Farmers' willingness to invest in livestock disease control

the case of voluntary vaccination against bluetongue

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Chapter 1

General introduction

1.1 Background

This thesis is motivated by the approach used by the Dutch animal health authorities to control the enduring bluetongue serotype 8 disease epidemic in 2008. National governments in Europe collaborate supranationally via the European Union (EU) and the World Organisation for Animal Health to improve the control of livestock diseases. The EU has put in place legislation for a number of livestock diseases, including bluetongue, indicating what control measures each member state should apply in case of an outbreak. A large epidemic of bluetongue virus serotype 8 in Europe started at the end of 2006. The required measures, such as movement restrictions, use of insecticides and indoor housing of livestock (European Council, 2000; European Council, 2007), did not sufficiently reduce the disease transmission in 2007. By the end of 2007, nearly 60,000 holdings with ruminants were affected (Wilson and Mellor, 2009).

New EU legislation was developed in 2008 in which it was proposed to apply a mass emergency vaccination campaign “to achieve the objectives of reducing clinical disease and losses, containing the spread of the disease, protecting free territories in the Member States and facilitating safe trade in live animals” (European Council, 2008). The Dutch animal health authorities used a voluntary vaccination approach and two types of policy instruments to motivate (incentivise) participation. A communicative intervention was implemented in which the government representatives as well as farmer organizations conveyed written or oral recommendations to the farmers to vaccinate their cattle. Subsidization of the vaccination costs was another policy instrument put in place (Ministry of Economic Affairs, 2008). From an epidemiological perspective, this approach was successful as only 66 new outbreaks were reported in 2008, compared to 6,500 in 2007 (Elbers et al., 2009b).

From an economic perspective, voluntary approaches are more flexible in terms of legislation while they can be effective at lower costs, since the *ex-ante* transaction costs of lobbying and legislation and *ex-post* transaction costs of surveillance and enforcement can be minimized (Furubotn and Richter, 1998; Segerson, 2013). The question remains whether a voluntary approach can be effective in controlling the transmission of bluetongue and other vector-borne livestock diseases.

The domain of the economics of animal health assesses the economic impact of livestock diseases and quantifies, compares and optimizes *ex-ante* as well as *ex-post* decision-making at various levels (Dijkhuizen et al., 1995). At the farm level, work in this field aims at making a farmer understand what, for example, the financial consequences are when disease control measures are adopted by the farmer (e.g. Hogeveen et al., 2011). In this sense, disease control can be seen as an on-farm input. Setting the marginal rates of substitution of inputs equal to their relative prices would give the economically optimal use of each input, including disease control. The optimal level of disease control can be such that a disease is allowed to some extent (McInerney, 1996).

It should be noted though that bluetongue, and many other livestock diseases, can affect not only the animal health status at the own farm but also at e.g. neighbouring farms. A farm's animal health status thus has public good characteristics, implying that externalities are involved. The extent to which the animal health status is a public good largely depends on the taxonomy of the livestock disease being dealt with. For example, the risk of a contagious disease outbreak within a certain region is dependent on the aggregate decision-making of all farmers within this region, while the level of private investments depends on the regional disease risk. Each private decision to invest or not in disease control (i.e. vaccination) has also an impact on the animal health status at neighbouring farms either positively or negatively. Theoretical studies in the domain of economics of animal health that account for the endogenous nature of infection risk predict that, due to these externalities, farmers likely underinvest in private disease control measures compared to the socially optimal level of investment (Beach et al., 2007; Gramig and Horan, 2011; Zilberman et al., 2012). Public intervention may then be justified when such market failures occur. Other market failures related to animal health arise from information asymmetries, resulting in moral hazard and adverse selection problems (e.g. Rushton et al., 2007; Hennessy and Wolf, 2015). Traditionally, public intervention followed a command-and-control approach of regulation and enforcement. Nowadays, the governance of animal health is shifting in the direction of a neoliberal model of cost and responsibility sharing, with forms of self-regulation being considered (Oude Lansink, 2011; Maye et al., 2014; Gilbert and Rushton, 2016).

The effectiveness of an intervention based on a voluntary approach (e.g. a vaccination scheme) depends on farmers' willingness to invest in disease control. Economic theory assumes the underlying decision-making process is such that farmers pursue the objective of maximising income and act in full rationality and self-interest. While still assuming these axioms, it is possible to include risk taking behaviour to the decision-making process using the expected utility criterion, and account as such for the widely accepted notion that farmers behave in a risk-averse manner (Ngategize et al., 1986; Hardaker et al., 2015).

Authors in the field of economics of animal health have suggested to go a step further and complement economic theory with insights from behavioural sciences (Edwards-Jones, 2006; Barnes et al., 2015; Gilbert and Rushton, 2016). Contextual factors that can be considered as key determinants of the willingness to invest in disease control are the experiential consequences of decisions (Elbers et al., 2010; Gethmann et al., 2015), in the economic literature known as non-use or passive values or nonpecuniary benefits (e.g. Lagerkvist et al., 2011; Howley, 2015). Other factors are perceptions of disease risk (Flaten et al., 2005; Valeeva et al., 2011), and of trust and confidence in the vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities (Palmer et al., 2009; Enticott et al., 2014). In reasoned action theory (Fishbein and Ajzen, 1975; Ajzen, 1991; Fishbein and Ajzen, 2010), these contextual factors are reflected in attitudinal and control beliefs. These social-psychological theories further emphasize that in the process of decision-making, farmers are likely influenced by their social environment, i.e. they perceive social pressures from different types of norms.

1.2 Problem statement

The scientific literature on farmers' willingness to invest in livestock disease control is fragmented and key findings from different research disciplines are not integrated. Economic studies on this subject emphasize the importance of understanding interactions between farmers' collective behaviour and disease epidemiology. The focus then is on the design and use of financial, incentive-based policy instruments to compensate for externalities. However, these models are limited in their ability to account for process and context in decision making and ignore non-economic motives to invest in disease control. For example, decision making might be partially driven by perceived social pressures to vaccinate from peers or other referents when the disease comes closer. If the willingness to invest in livestock disease control is also driven by intrinsic and social motives, this could imply that not only financial compensation, but a mix of policy instruments is needed to reach effectiveness and maximum efficiency. Effectiveness refers to reaching the objective of controlling disease spread. Efficiency refers to the ratio between costs and benefits. This asks for an integrated research approach that considers (1) the heterogeneity in farmers' responses to policies based on the idea that farmers differ in their motives to invest in livestock disease control and at the same time (2) the interplay between farmers' collective behaviour and animal disease epidemiology.

1.3 Research objectives

This thesis will apply economic and social psychological theories and methods on the case of bluetongue vaccination to identify and assess economic and non-economic motives to invest in livestock disease control. The overarching research objective of this thesis was to assess the key determinants of farmers' willingness to vaccinate against bluetongue and study the impact of different policy designs on the effectiveness of voluntary vaccination approaches to bluetongue disease control.

Specific objectives were to:

RO1. model and evaluate farmers' willingness to vaccinate against bluetongue considering economic motives only;

RO2. identify and assess the relative importance of key social-psychological constructs in explaining the willingness to vaccinate against bluetongue;

RO3. identify and assess the beliefs underlying the key social-psychological constructs that drive the farmers' willingness to vaccinate against bluetongue;

RO4. explore the factors explaining heterogeneity in beliefs that drive the farmers' willingness to vaccinate against bluetongue;

RO5. assess farmers' willingness to vaccinate against bluetongue under different policy designs, considering economic, intrinsic and social motives;

RO6. model and evaluate farmers' willingness to vaccinate against bluetongue under different policy designs, considering economic, intrinsic and social motives and the interplay between farmers' collective behaviour and disease epidemiology.

1.4 Methodology

A three-stage research approach was conducted, as shown in Figure 1. Starting point in reasoning how farmers make a decision to invest in livestock disease control is expected utility theory (EUT). It is assumed in EUT that people behave as if information is processed to form perception and beliefs, and preferences are primitive, consistent, and immutable (Ben-Akiva et al., 1999; McFadden, 1999). The decision-making process is treated as a black box; it does not consider *how* people form preferences and make choices. The decision is ruled by a set of mathematical axioms that assume a rational decision maker. In the context of livestock disease control decision making, the EUT considers usually the economic risk and monetary outcomes of the decision, intrinsic or social aspects are neglected (Hardaker et al., 2015).

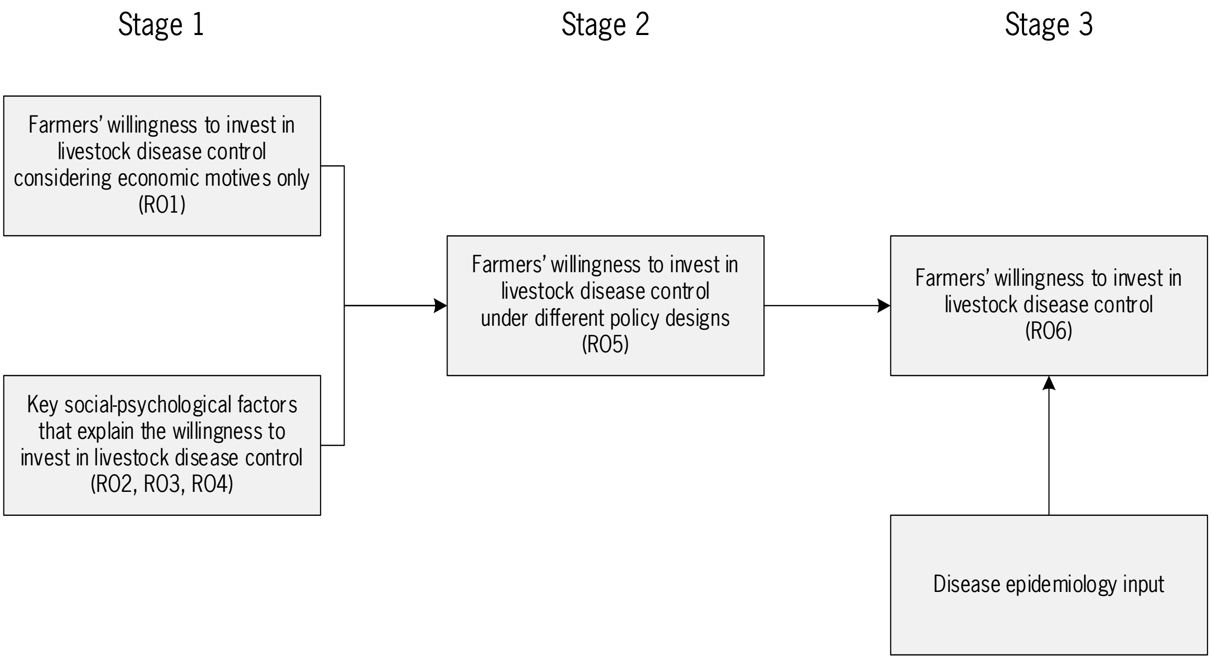

Figure 1-1: A three-stage research approach to modelling farmers' willingness to invest in livestock disease control.

The first stage in this thesis consisted of applying two models of decision making on the farmers' decision problem of vaccination against bluetongue: the EUT and the reasoned action approach (RAA) from social psychology, which is the latest formulation of the reasoned action theory (Fishbein and Ajzen, 2010). The motivation for applying both models was to get a richer understanding of how farmers make their decision to invest in livestock disease control. In contrast to the EUT, in the RAA farmers' decision-making process is not constrained by economic rationality.

The only assumption made is that an individual's (intended) behaviour follows reasonably from beliefs, which are decomposed into attitudinal, normative and control beliefs. These beliefs may be inaccurate, biased, or even irrational (Ajzen and Fishbein, 2005).

One way to assessing the process and context of decision making in economic models is to include social-psychological constructs of behaviour. The integrated choice and latent variable (ICLV) model is an extended discrete choice model, in which next to preferences, these constructs are modelled to account for heterogeneity in preferences. It offers a general econometric framework to supplement economic theory with concepts or theories from social sciences (Walker and Ben-Akiva, 2002; Walker et al., 2007; Ben-Akiva et al., 2012). Some of the process (steps involved in decision making) and context (factors affecting the process) are taken into account, and so enhance the behavioural representation in economic models.

The second stage involved the development and testing of a generalized random utility model of farmers' behaviour that allowed for heterogeneity in motives to invest in bluetongue disease control. The ICLV model was used as the overall modelling framework and a discrete choice experiment was designed to obtain farmers' preferences for different voluntary bluetongue vaccination designs. Findings from the first step were used in two ways. First, to capture different perceptions of farmers associated with livestock disease control in some attributes of the vaccination scheme. Second, to select the social-psychological constructs and relevant farm characteristics that could explain preference heterogeneity for these attributes. As such, economic, intrinsic and social motives to invest in livestock disease control were taken into account.

In the third stage, an agent based model of the interplay between farmers' collective behaviour and bluetongue disease epidemiology was developed. The utility model developed in the second stage was employed to represent decision making, and was connected with a social network structure. Two simple heuristics update the social-psychological constructs, and subsequently utility, using temporal and spatial information available from the simulation model. Farmers observe the number and closeness of bluetongue infected farms and construct a measure of risk perception. Farmers observe the number of vaccinated network links and construct a measure of perceived social pressure to vaccinate. The epidemiology of bluetongue was modelled by a susceptible-latent-infectious-recovered (SLIR) model, in which the distance dependent transmission from an infected farm to a susceptible farm is modelled stochastically by a Poisson process. The effectiveness of different policy designs (from the choice experiment) was simulated in terms of disease rate and vaccination uptake.

Table 1 shows in which way data were collected to address the research objectives specified. Decision analysis was used for RO1 to structure the bluetongue vaccination problem into decisions, events and payoffs, and to define the relationships among these elements (Clemen and Winkler, 1999; Hardaker et al., 2015). Probabilities were estimated by experts, payoffs were based on values from the bluetongue literature.

Table 1-1: Overview of the research approaches used in this thesis.

Research objective	Model of decision making	Statistical or simulation method	Model parameterisation
RO1	Expected utility theory	Decision (tree) analysis, Monte Carlo simulation	Expert consultation Values from the literature
RO2	Reasoned action approach	Structural equation model	First random sample of 1,500 Dutch dairy farms. Data obtained via a survey based on the reasoned action approach.
RO3		Structural equation (MIMIC) model	
RO4		Cluster analysis, Multinomial logit model	
RO5	Random utility / Discrete choice theory, Integrated choice and latent variable model approach	Conditional logit model, Mixed logit model	Second random sample of 1,500 Dutch dairy farms. Data obtained via a choice experiment survey.
RO6		Agent based model simulation	

A first survey was developed for RO2, RO3 and RO4 based on the reasoned action approach. Farmers' beliefs were first identified and elicited from semi-qualitative interviews held in May/June 2013 with 7 dairy farmers and 1 veterinarian from different parts within the Netherlands. The survey was sent in January 2014 to a random sample of 1,500 Dutch dairy farms that was drawn from the National Cattle Identification and Registration Database. The survey data was analysed using several, mostly multivariate, statistical techniques.

A survey-based discrete choice experiment was developed for RO5 and RO6. The survey was sent in April 2015 to a random sample of 1,500 other Dutch dairy farms that was drawn from the National Cattle Identification and Registration Database. The survey data was analysed using several econometric models. Farmer profiles and estimations from the econometric model were used in the agent based model simulation.

1.5 Thesis outline

This thesis consists of eight chapters. The general introduction and general discussion are the first and final chapter. Each of the six chapters in between addresses one of the research objectives that were defined in section 1.3. Chapter 2 corresponds with RO1, and evaluates farmers' expected utility based on the monetary net benefits of voluntary vaccination against bluetongue.

Chapter 3 corresponds with RO2, and assesses the social-psychological constructs that predict the intention to vaccinate against bluetongue and are functional for the design of voluntary vaccination strategies. Chapter 4 corresponds with RO3, and assesses which beliefs underlying the social-psychological constructs drive the intention to vaccinate against bluetongue and evaluates the vaccination strategy implemented by the Dutch animal health authorities in 2008. Chapter 5 corresponds with RO4, and explores whether there is heterogeneity in farmers' attitudinal beliefs about vaccination against bluetongue, and which factors are associated with the heterogeneity.

Chapter 6 corresponds with RO5, and assesses farmers' preferences for bluetongue vaccination scheme attributes and explains preference heterogeneity by linking it to social-psychological constructs and farm and farmer characteristics. Chapter 7 corresponds with RO6, and simulates the disease rate and vaccination uptake under different policy designs.

Chapter 8 provides a synthesis of the results found throughout this thesis. The implications for policy making are subsequently discussed, followed by the main scientific contributions of this thesis, and suggestions for future research.

Chapter 2

Expected utility of voluntary vaccination in the middle of an emergent bluetongue virus serotype 8 epidemic: a decision analysis parameterized for Dutch circumstances

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Abstract

In order to put a halt to the bluetongue virus serotype 8 (BTV-8) epidemic in 2008, the European Commission promoted vaccination at a transnational level as a new measure to combat BTV-8. Most European member states opted for a mandatory vaccination campaign, whereas the Netherlands, amongst others, opted for a voluntary campaign. For the latter to be effective, the farmer's willingness to vaccinate should be high enough to reach satisfactory vaccination coverage to stop the spread of the disease. This study looked at a farmer's expected utility of vaccination, which is expected to have a positive impact on the willingness to vaccinate.

Decision analysis was used to structure the vaccination decision problem into decisions, events and payoffs, and to define the relationships among these elements. Two scenarios were formulated to distinguish farmers' mindsets, based on differences in dairy heifer management. For each of the scenarios, a decision tree was run for two years to study vaccination behaviour over time. The analysis was done based on the expected utility criterion. This allows to account for the effect of a farmer's risk preference on the vaccination decision. Probabilities were estimated by experts, payoffs were based on an earlier published study.

According to the results of the simulation, the farmer decided initially to vaccinate against BTV-8 as the net expected utility of vaccination was positive. Re-vaccination was uncertain due to less expected costs of a continued outbreak. A risk averse farmer in this respect is more likely to re-vaccinate. When heifers were retained for export on the farm, the net expected utility of vaccination was found to be generally larger and thus was re-vaccination more likely to happen.

For future animal health programmes that rely on a voluntary approach, results show that the provision of financial incentives can be adjusted to the farmers' willingness to vaccinate over time. Important in this respect are the decision moment and the characteristics of the disease. Farmers' perceptions of the disease risk and about the efficacy of available control options cannot be neglected.

Keywords

bluetongue, emergent disease, voluntary vaccination, decision-making, risk aversion, risk perception

2.1 Introduction

Introduction of a vector-borne disease can have large socio-economic consequences, in terms of production, policy and trade (Burrell, 2002). bluetongue virus serotype 8 (BTV-8) appeared in north-western Europe in August 2006, where this serotype was previously unknown to the European Union (EU). This specific serotype affected also cattle with clinical disease, whereas symptoms of other serotypes usually were seen in sheep (Elbers et al., 2008a).

In response to this outbreak, the Dutch government started to put reactive measures into place based on EU Directive 2000/75/EC. The Directive stipulated the disease should be combatted and eradicated using control, monitoring, surveillance and restrictions on movements of susceptible animal species (European Council, 2000; European Council, 2007). In detail, measures entailed diagnostics, mandatory indoor housing of ruminants, medical treatment of animals, treatment of stables and vehicles for animal transport with insecticides, extra testing of animals for export and movement restrictions (Velthuis et al., 2010). Nevertheless, many new outbreaks were reported after July 2007. This indicated that BTV-8 had survived successfully the winter of 2006, despite hopes that the cold seasonal temperatures would have constrained the outbreak (Wilson and Mellor, 2009). In order to put a halt to the BTV-8 epidemic, the EU Commission promoted a vaccination campaign at transnational level to be started in the spring of 2008. It was expected that the virus would be manageable by an effective use of vaccination (Wilson and Mellor, 2008). Furthermore the Commission decided to provide financial incentives “to prevent the spread of the disease as rapidly as possible” (European Council, 2008). Member states like Belgium and Germany opted for a mandatory vaccination campaign. Other member states, such as the United Kingdom (UK) and the Netherlands, decided to offer their farmers a voluntary vaccination program with provision of financial incentives. In the Netherlands, bad experiences of cattle farmers with a past mandatory vaccination campaign against Infectious Bovine Rhinotracheitis, when a batch of vaccines was contaminated, were amongst the reasons to adopt a voluntary program (Elbers et al., 2010). The main reasons to adopt a voluntary program in the UK were to minimize the regulatory burden on the industry and avoid a costly system of enforcement to check compliance (2008).

The financial consequences in the Netherlands until the year in which the vaccination programme took place were estimated to be €32.4 million in 2006, mainly because of indirect costs of control and diagnosis. In the subsequent year, the costs were estimated at €170 million Euros, primarily as a result of direct costs of the disease (Velthuis et al., 2010).

The effectiveness of the vaccination programs within each member state are not known for all EU countries. For the Netherlands a vaccination coverage of 70 – 80% was reached in 2008 (Elbers et al., 2010) and new infections in the subsequent years were not reported.

Before and during a voluntary vaccination campaign, it was unclear whether the costs and responsibility sharing with the farmer community led to a successful uptake, and what the effect of providing financial incentives would be. In the UK, some veterinary experts discussed the responsibility of the government in the control of diseases such as bluetongue (e.g. Brownlie, 2008; Orpin, 2008). The central element of discussion was the trade-off between effectiveness and efficiency, between a guaranteed high vaccination coverage for eradication with higher government spending on enforcement (mandatory) and on the other hand a vaccination campaign with less certainty about the resulting coverage, but more efficient and fast distribution of vaccines and less public spending (voluntary). For the latter, the farmer's willingness to vaccinate had to be high in order to reach a coverage that eradicated BTV-8, which is the leading goal (European Council, 2000). The coverage aimed for to prevent between herd-transmission was 80 per cent (Velthuis et al., 2011).

In the field economics of animal health, only a few studies looked specifically at voluntary participation in animal health programmes. The voluntary participation in pre-outbreak animal disease insurances was studied with special attention to the risk attitude and/or risk perception of farmers (Ogurtsov et al., 2009; Niemi and Heikkilä, 2011). For vaccination – that might be considered as insurance before, during or after an epidemic – the collective effectiveness of a voluntary campaign was studied for a theoretical endemic disease comparable to Bovine Viral Diarrhoea (Rat-Aspert and Fourichon, 2010). In these studies, the characteristics of the disease and the decision moment differed. These factors were considered to be important decision variables when modelling the vaccination behaviour, just as the risk attitude of farmers.

This study contributes to the existing literature by providing a decision model that can be used as a basic framework to assess a farmer's expected utility of an intervention to control disease, such as vaccination. Furthermore, with this decision model we simulated the farmer's expected utility of (voluntary) vaccination in the middle of an emergent BTV-8 epidemic, to study determinants of the willingness to vaccinate, which is expected to increase with the expected utility of vaccination. The results of this study can be used to evaluate the effectiveness of policy instruments, e.g. provision of financial incentives that encourage a successful uptake of voluntary vaccination.

2.2 Materials and methods

This study used decision analysis, utilizing a decision tree, to simulate the farmer's decision to vaccinate against BTV-8 as part of the public voluntary vaccination programme. Decision analysis is a prescriptive model of choice based on logical derivations from some axioms ruling how a Decision Maker (DM) would act in making risky decisions. Risk is defined here as uncertain consequences (Hardaker et al., 2004). The corresponding axioms that allow to derive a DM's expected utility in a consistent way is, for example described by Clemen and Reilly (1999). In this study the farmer has been conceptualized as a rational economic DM that maximizes expected utility (see Seegers et al., 1994; Hardaker et al., 2004).

Strong assumptions were made on the structure of the decision problem. In decision analysis the decision problem is split into separate events or uncertain states of nature, and related consequences or payoffs. The belief of the DM about the likelihood of occurrence of an event is reflected with a probability . A payoff indicates what happens in terms of income, given the decision taken and the related event(s) that occur (Hardaker et al., 2004). The analysis was done using Precision Tree and @Risk (Palisade Inc., NY, USA), both add-in software to MS Excel.

2.2.1 Structuring the problem

2.2.1.1 Influence diagram

We used an influence diagram to firstly structure the decision problem into decisions, events and payoffs and then define the relationships among these elements (Hardaker et al., 2004).

The decision to vaccinate has economic and epidemiologic consequences. In Figure 1, epidemiological relationships are indicated with solid arrows. Vaccination reduces the probability of being confronted with disease effects of the BTV-8 outbreak. Over time, it lowers the national herd susceptibility against BTV-8 because of less virus circulation, which in turn lowers the herd exposure on a single farm. In Figure 1, economic relationships are indicated with dashed arrows. Vaccination ensures that direct costs of disease effects of BTV-8, such as production losses and fertility problems, are minimized. Furthermore, it ensures that export of heifers can be continued independently of what the national BTV-8 status is, thereby avoiding a drop of heifer prices. Both effects finally impact the income.

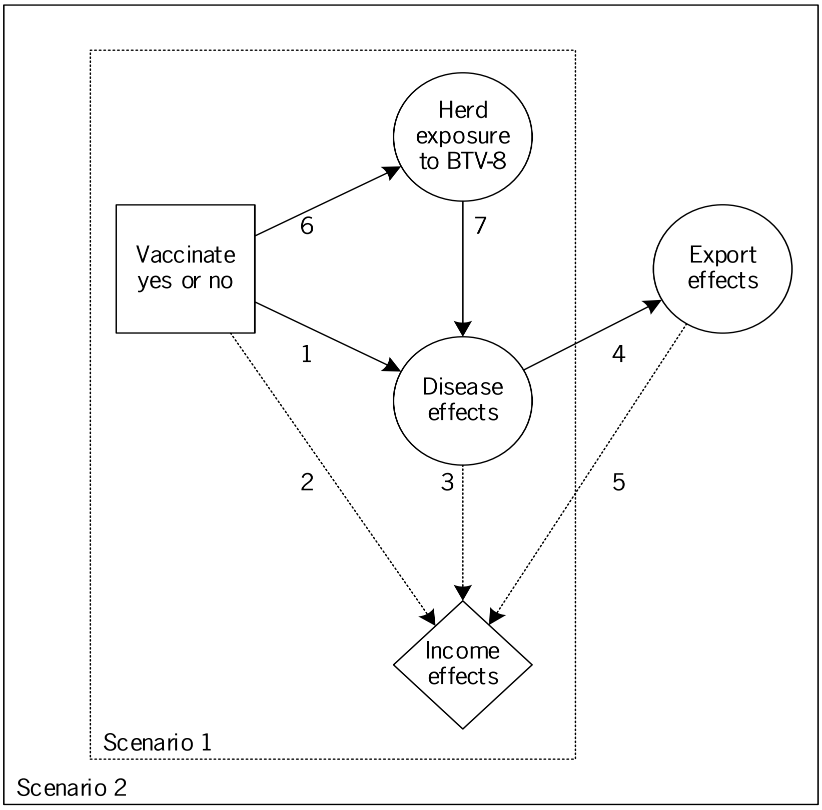

Figure 2-1: Influence diagram for the decision to vaccinate against BTV-8 in one year. A square represents a decision, a circle represents an event and a diamond indicates the consequence of the interaction between decisions made and the events.

The set of relationships taken into account by the DM determines to a large extent the outcome of the decision problem. The key basic consideration is that vaccination reduces the impact of BTV-8, costs of vaccination are weighted against the (direct) costs and likelihood of disease. In Figure 1, this consideration is represented by relationships 1, 2 and 3. Another consideration relates to dairy heifer management aimed at rearing heifers for export, in Figure 1 represented by relationships 4 and 5.

Over time, a high vaccination uptake can be effective in controlling the transmission of BTV-8 thereby reducing the incidence of outbreaks, and hence is dependent on the aggregated decision to vaccinate of the whole sector. However, an initial high vaccination uptake might lead to a decision not to vaccinate in the subsequent year when costs of vaccination are weighed against the expected costs of a continued outbreak (Rat-Aspert and Fourichon, 2010). This third consideration is represented by relationships 6 and 7 in Figure 1.

In summary, the scenarios formulated distinguished two different DM's mind sets. In scenario 1, the basic consideration was studied. In scenario 2 the consideration related to heifer export was added to the basic consideration. For each of the scenarios a decision tree was solved. Both scenarios were run for two years to study the third consideration, which is vaccination behaviour over time.

2.2.1.2 Decision tree

As structured with the influence diagram (scenarios), a decision tree was made to represent the decision problem chronologically and in greater detail. Figure 2 shows a decision tree to illustrate the decision problem in each scenario. The full tree is a representation of scenario 2 for the two years. Scenario 1 is represented by a part of this tree, excluding the event export restriction (EXR).

For each decision tree, at first the decision to vaccinate or not had to be made. A positive decision implied expenditures, the costs of vaccinating the herd. After the decision to vaccinate, the DM was subject to some events. For the basic consideration studied in scenario 1, these were the events of herd exposure to BTV-8 and of being confronted with disease effects (Figure 2). Probabilities and payoffs were assigned to all events. The decision outcome can influence probability values. For example, the decision to vaccinate reduced the probability of being confronted with direct costs of BTV-8 to approximately zero.

For year 1, three probabilities were derived for scenario 1. The first probability was herd exposure (HE_1) to BTV-8 at the start of the outbreak. For each event, the probabilities of two branches necessarily have to add up to 1. With this rule, the probability of for example no herd exposure can be calculated. Then, if the herd was exposed, the probability of being confronted with disease effects (DE_1), depends on whether the herd has been vaccinated (V_1), or not (NV_1). Export of heifers was only allowed if it was proven, by use of a diagnostic test, that no BTV-8 was circulating or that vaccination took place (European Council, 2007). The event added was a diagnostic test result indicating presence of BTV-8 after which an export restriction was put in place (EXR_1) when the result was negative. Vaccination on forehand reduced the probability of disease effects and thus indirectly the probability of a negative test result, indicating disease presence.

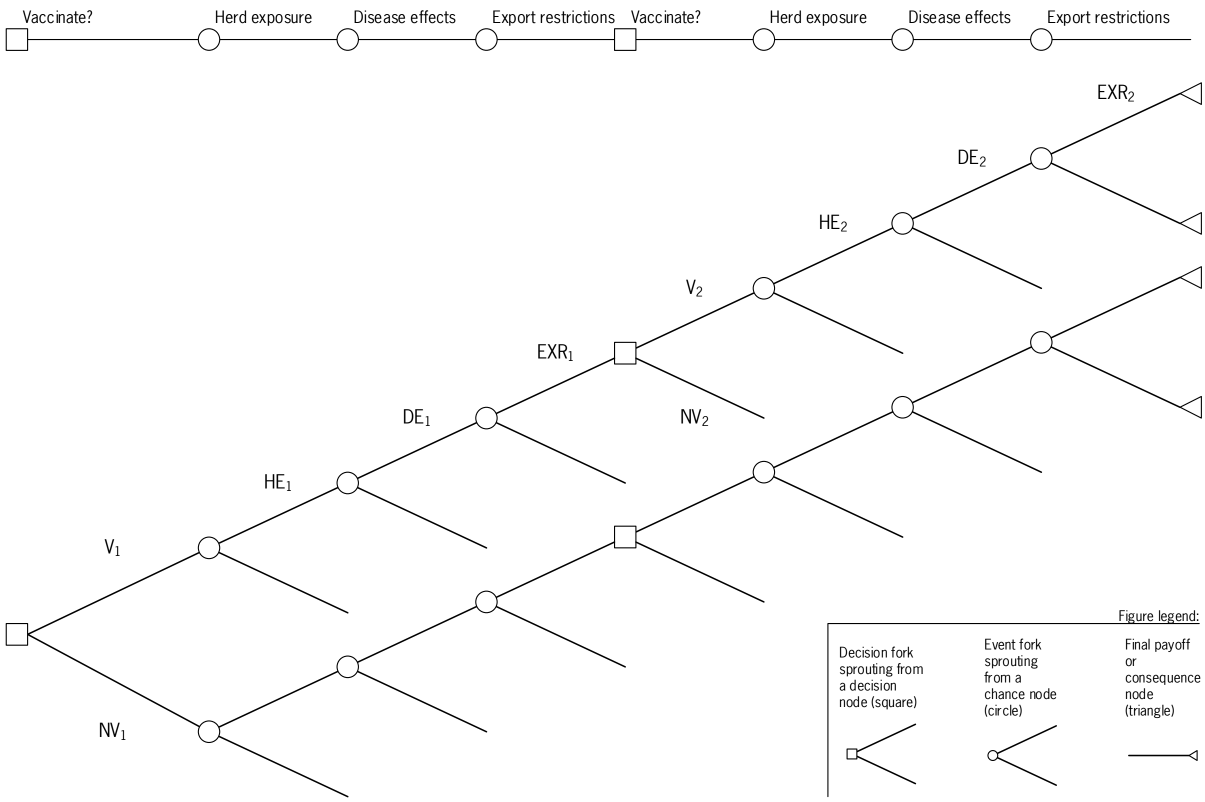

Figure 2-2: Decision tree representation of the vaccination problem for two years. After deciding to vaccinate (V or NV), the events of herd exposure (HE), disease effects (DE) and export effects (restriction) (EXR) follow.

The likelihood of a continued outbreak (year 2) was captured by the probability of herd exposure HE_2. A large vaccination uptake by the farmer community in year 1 lowered HE_2compared to HE_1. The likelihood thus depended on the aggregated decision to vaccinate of the farmer community, while the private decision to revaccinate depended on that changing likelihood (Beach et al., 2007). This endogenous process was difficult to capture in a probability but should contain the DM's belief on the vaccination decisions of the farmer community, combined with the epidemiological consequences of that uptake.

Considering (re-)vaccination in year 2, the probability of being confronted with disease effects (DE_2) depended on what happened in year 1 of the outbreak and the initial vaccination decision made by the DM. A herd previously infected by the disease may develop lifelong immunity in which case no disease effects are observed (Elbers et al., 2010). If the herd was vaccinated in year 1 and disease effects did not appear (NDE_1) intermediately, the probability of DE_2 was reduced due to continuing but decreasing efficacy of the initial vaccine. Besides disease effects, also export effects (EXR_2) depended on the outcomes of previous events and the initial vaccination decision in year 1.

2.2.2 Risk preferences

Incorporating the attitude towards risk is useful since it was an important consideration in the decision-making process to vaccinate for BTV-8 (Elbers et al., 2010). Although farmers are commonly assumed to be risk averse (Hardaker et al., 2004), it was not clear how risk is considered and taken into account in the decision to vaccinate. For example, the time-point when the decision problem occurs is important to the DM; the risk attitude may be considerably different in the middle of an outbreak situation compared to a disease-free situation. A single utility function cannot represent these two situations and therefore can only be specified for a short period of time under a given set of circumstances (Ngategize et al., 1986).

In this study, a negative exponential utility function (1) was considered to reflect a DM's risk preference:

$$U(w) = 1 - exp^{-w/R}, w > 0, R > 0 \quad (1)$$

where w is income and R is a parameter that captures the risk tolerance and describes the curvature of the utility function. Utility is maximized through income. The risk tolerance indicates how much risk (in terms of income) the DM is willing to take. In studies in economics of animal health, usually the risk aversion coefficient is used to study risk attitudes (e.g. Rat-Aspert and Fourichon, 2010; Niemi and Heikkilä, 2011), whereas the risk tolerance concept more often is used within financial economic literature (Clemen and Reilly, 1999). However, both concepts are closely related as the risk aversion coefficient is the reciprocal of risk tolerance (Pratt (1964) in: Clemen and Reilly, 1999). By fluctuating R, the attitude towards risk can be varied. A low R indicates high risk aversion; the curve corresponding to the utility function becomes more concave. When R becomes infinite, the curve is flat, representing risk neutrality. The utility function in (1) has constant absolute risk aversion (CARA) properties: income does not affect the degree of risk aversion.

Impact of risk aversion on the vaccination decision was studied by comparing the certainty equivalents (CE). The CE is defined as: the amount of money (in terms of income) that is equivalent to a given situation that involves uncertainty (Clemen and Reilly, 1999). It can be obtained by taking the inverse of (1):

$$U(CE) = -R[ln(-U(w) + 1)], w > 0, R > 0. \quad (2)$$

If the DM is risk neutral, the CE is equal to the expected monetary value (EMV). If the DM is risk averse, the $CE > EMV$.

The effect of risk aversion on the decision outcomes was studied with different predefined risk tolerance levels set. Savings were taken as a proxy for the risk tolerance level. The risk tolerance levels (R) were set to €30,000 for a hardly risk averse DM and €3,000 for a highly risk averse DM. The first number corresponded with the average savings of an average dairy farm between 2004 – 2006 (LEI/CBS, 2008) and the latter value is 10 per cent of this. An infinite risk tolerance level represented a risk neutral DM.

2.2.3 Model parameterization

The voluntary vaccination program in The Netherlands took first place in May 2008 (Elbers et al., 2010). At that time, many farms in a large part of the Netherlands had been infected with BTV-8 in the former two years. However, farms located in the Northern provinces were barely affected (Velthuis et al., 2011), and thus still susceptible to the disease. The starting point of the model was an average dairy farm located in an area with susceptible herds for BTV-8. Statistics indicated that the average dairy farm had a herd size hs of 76 cows (LEI/CBS, 2008). Other cattle production systems else than dairy farms were not considered in this study; in the Netherlands, most cattle farms are dairy farms and represent also the highest economic value in the cattle production sector. Based on Elbers et al. (2008b), it was assumed that only dairy cows would be clinically affected and not young stock and calves.

First, the decision itself could only be taken at some costs: the total costs of vaccinating the herd V, assuming that the entire herd, including young stock and calves, was vaccinated. It was calculated as:

$$V = 2 \times (cf + hr \times du + (hs + hs \times rr \times ca) \times (vc + dm + rc)), \tag{3}$$

where $du = 10 + 0.5 \times (hs + (hs \times rr \times ca))$, $\quad (4)$

cf the call-out fee, hr the hourly rate of the veterinarian, du the duration of the herd vaccination, the numbers 10 and 0.5 stand for the preparation time and the time of one vaccine administration respectively, hs the herd size, rr the replacement rate, ca the calving age, vc the cost of a vaccine dosage, dm the cost of dispense material of one dosage and rc is the cost of registering each dosage. The resulting input parameters are summarized in Table 2. The herd vaccination had to be done twice (Schwartz-Cornil et al., 2008), so total costs of vaccinating the herd were multiplied by two. Total costs of vaccination at a farm with export activities V_{exp} were slightly higher due to a higher proportion of young stock and calves being kept (see Appendix I).

Table 2-1: Description of the input parameters used for calculating the economic consequences of vaccination against BTV-8 for the average Dutch dairy farm in 2008.

Variable	Description	Unit	Input parameter	Source
cf	Call-out fee veterinarian	euro/visit	20.58	Velthuis et al., 2011
hr	Hourly rate veterinarian	euro/hour	116.17	Velthuis et al., 2011
hs	Average herd size	# dairy cows	76	LEI/CBS, 2008
rr	Replacement rate	%	28	Mohd Nor et al., 2013a
dr	Drop-out rate	%	8	Mohd Nor et al., 2013a
ca	Calving age	years	2.25	Mohd Nor et al., 2013b
vc	Vaccine costs	euro/dosage	0.40	Velthuis et al., 2011
dm	Dispense material costs	euro/dosage	0.02	Velthuis et al., 2011
rc	Registration costs	euro/dosage	0.05	Velthuis et al., 2011

2.2.3.1 Payoffs

Payoff calculations were based on a deterministic economic model (Velthuis et al., 2010). The model was adjusted for the assessment of the total loss from the BTV-8 epidemic for an individual (average) dairy farm and is described by:

$$L = (DC + TC + PL) + EXR, \tag{4}$$

where L are the total losses at a dairy farm, DC the diagnostic costs, TC the treatment costs and PL the production losses. The latter are associated with mortality, reduced milk production, weight losses and fertility and gestation problems and were calculated in the same way as Velthuis et al. (2010). These cost categories together made up the total direct costs of the disease.

Export restrictions EXR are indirect costs. It is the yearly number of heifers that regularly is exported, multiplied by the price change as a result of the export restriction. This was calculated as:

$$EXR = (hs - hs \times rr) \times \frac{365}{ci} \times 0.5 \times (1 - dr) \times ev_h - sv_h, \tag{5}$$

where ci is the calving interval, dr the drop-out rate, ev_h the export value of a heifer, sv_h the slaughter value of a heifer. The value 0.5 is included because only half of the newborn calves are female (assumption). A full description of the costs calculations is given in Appendix I.

2.2.3.2 Probabilities

Hardaker and Lien (2010) indicate that if relevant frequency data are lacking, expert advice can be a good other source. For lack of frequency data of the disease occurrence, expert judgements were used to estimate probabilities that relate to the epidemic of 2008 and the consequences for the year after. This was done by two senior Dutch veterinary epidemiologists from the Central Veterinary Institute, who gained experience with the BTV-8 epidemic. The procedure of elicitation was as follows: both experts were asked to make their probability judgements individually. Each probability then was jointly discussed and added to the model after the experts agreed upon distribution type and range.

Probability values and their statistical distributions are presented in Table 3. The table should be read as follows: the probability of herd exposure in year 1 (HE_1) is defined as a Pert distribution with minimum value 0.9, most likely value 0.95 and maximum value 1. This corresponds with the upper branch in the event 'Herd Exposure' in Figure 2. By definition, the Pert distribution of no herd exposure then is (0, 0.05, 0.1), because probabilities in one node necessarily have to add up to 1. This corresponds with the lower branch in the event 'Herd Exposure' in Figure 2.

Three types of distributions were used. Pert and triangular distributions are often used to describe distributions from expert opinion, where a Pert distribution is more natural than a triangular distribution (Vose, 2000). Therefore, natural phenomena, such as herd exposure, were described with a Pert distribution and the more static properties of a test result with a triangular distribution. A uniform distribution was used to describe HE_2. No knowledge was available on this probability and therefore it was defined as a uniform probability distribution around the expected mean.

2.2.4 Model run, output definition and validation

Using Monte Carlo simulation, all decision tree models were run, taking into account the probability distributions set by experts as inputs and expected economic consequences derived from the model. Both decision options – either do vaccinate or do not vaccinate – were defined as outputs. Furthermore, one additional output was defined as the difference between both decision options, which can be considered as the net expected utility of vaccination, measured in terms of income losses. Thus, for each iteration, the expected utility (represented as income losses) of both decision options and their difference were calculated simultaneously. From the resulting distributions, their minimum, mean, median and maximum were reported. A positive net expected utility of vaccination indicates that the income loss of vaccination is lower than the income loss of no vaccination, and vice versa. Model iterations continued until the expected standard deviation of the defined decision outputs converged (with a 3 per cent tolerance and 95 per cent confidence level). This was done to guarantee stable and reliable output statistics.

The outputs – income losses on which the decision is taken – derived could not be externally validated as empirical data on income losses from BTV-8 infection is lacking. Instead, internal validation was used to assess the validity of the model. First, inputs were compared with outputs to check for unexpected relationships that could indicate errors in formulae and parameterization of the payoffs and probabilities. Moreover, as a sensitivity analysis, the economic consequences of BTV-8 as estimated by Santman-Berends (2011) were used to check the robustness of the predictions of the decision model.

Table 2-2: Description of the probability values and their statistical distributions used in the decision tree.

Probability	Value	Distribution	Description
HE_1	0.9, 0.95, 1.0	Pert	Herd exposure in yr. 1.
$DE_1 \mid V_1$	0, 0.001, 0.005	Pert	Disease in yr.1 given vacc. in yr. 1.
$NDE_1 \mid NV_1$	0.9, 0.95, 1.0	Pert	Disease in yr. 1 given no vacc. in yr. 1.
HE_2	0.3, 0.9	Uniform	Herd exposure in yr. 2.
$DE_2 \mid V_2, NDE_1V_1$	0, 0.001, 0.005	Pert	Disease in yr. 2 given vacc. in yr. 2, and given vacc. and no disease in yr. 1.
$DE_2 \mid NV_2, NDE_1V_1$	0.1, 0.2, 0.3	Pert	Disease in yr. 2 given no vacc. in yr. 2, and given vacc. and no disease in yr. 1.
$DE_2 \mid V_2, DE_1V_1$	0, 0.0001, 0.0005	Pert	Disease in yr. 2 given vacc. in yr. 2, and given vacc. and disease in yr. 1.
$DE_2 \mid NV_2, DE_1V_1$	0, 0.0001, 0.0005	Pert	Disease in yr. 2 given no vacc. in yr. 2, and given vacc. and disease in yr. 1.
$DE_2 \mid V_2, DE_1NV_1$	0, 0.0001, 0.0005	Pert	Disease in yr. 2 given vacc. in yr. 2, and given no vacc. and disease in yr. 1.
$DE_2 \mid NV_2, DE_1NV_1$	0, 0.01, 0.05	Pert	Disease in yr. 2 given no vacc. in yr. 2, and given no vacc. and disease in yr. 1.
$DE_2 \mid V_2, NDE_1NV_1$	0, 0.001, 0.005	Pert	Disease in yr. 2 given vacc. in yr. 2, and given no vacc. and no disease in yr. 1.
$DE_2 \mid NV_2, NDE_1NV_1$	0.9, 0.95, 1.0	Pert	Disease in yr. 2 given no vacc. in yr. 2, and given no vacc. and no disease in yr. 1.
$EXR_1 \mid DE_1$	0.95, 0.99, 1.0	Triang	Neg. test result in yr. 1 given disease in yr. 1.
$EXR_1 \mid NDE_1, V_1$	0, 0.01, 0.05	Triang	Neg. test result in yr. 1 given vacc. and no disease in yr. 1.
$EXR_1 \mid NDE_1, NV_1$	0.4, 0.5, 0.6	Triang	Neg. test result in yr. 1 given no vacc. and no disease in yr. 1.
$EXR_2 \mid DE_2$	0.95, 0.99, 1.0	Triang	Neg. test result in yr. 2 given disease in yr. 2.
$EXR_2 \mid NDE_2, V_2$	0, 0.01, 0.05	Triang	Neg. test result in yr. 2 given vacc. and no disease in yr. 2.
$EXR_2 \mid NDE_2, NV_2, NV_1$	0.4, 0.5, 0.6	Triang	Neg. test result in yr. 2 given no vacc. and no disease in yr. 2, and given no vacc. in yr. 1.
$EXR_2 \mid NDE_2, NV_2, V_1$	0.2, 0.25, 0.3	Triang	Neg. test result in yr. 2 given no vacc. and no disease in yr. 2, and given vacc. in yr. 1.

2.3 Results

2.3.1 Economic consequences

Table 4 presents the expected economic consequences of the BTV-8 outbreak for the average Dutch dairy farm. The costs of vaccinating the herd were estimated as €436. For a dairy farm that exported heifers, the costs of vaccinating the complete stock were slightly higher at €502 because such a farm retains more animals. For an infected farm the direct costs were estimated at €5,339 including costs of diagnosis, treatment and production losses. The latter was for almost three-quarters the result of gestation problems (see Velthuis et al., 2010). When a part of the heifers was retained for export due to heifer management aimed at rearing own dairy cows, BTV-8 infection could result in another loss of €6,832 mainly because of lower prices for heifers in case they cannot be exported.

Table 2-3: Overview of the costs of vaccination and of the expected economic consequences of BTV-8 for the average Dutch dairy farm in Euros.

Vaccination costs	Direct costs			Indirect costs
Herd vaccination	Diagnosis	Treatment	Production losses	Export restriction
436 (502)	79	840	4420	6832

2.3.2 Expected utility of vaccination

Based on the convergence criteria set, 8,550 iterations were needed to guarantee stable and reliable outcomes.

The decision outcomes for scenario 1 are presented in Table 5 for all five decision moments. In year 1, at the start of the outbreak, there was only one decision moment. In year 2, four decision moments had to be simulated, based on the decision chosen and related events earlier in year 1.

In year 1 of the outbreak, vaccination was the best decision with a net expected utility of vaccination calculated, ranging from €3,950 to €4,777 with a median of € 4,373. Since V_1 at the start reduces the probability of disease, the most likely decision moment entered in year 2 was with NDE_1 before. In that case, the best decision was to re-vaccinate. However, the net expected utility of re-vaccination this time ranged from €-253 to €914, with a median of €178.

Table 2-4: Overview of the decision outcomes for scenario 2, represented as income losses in Euros. The underlined vaccination decisions indicate the policy suggestion which is the optimal route when the full tree is run.

Decision moment	Intermediate events passed		Vaccinate?	Income losses			
				Min	Mode	Median	Max
Year 1	NA		YES	436	447	443	459
			NO	4,391	4,838	4,816	5,217
			Net exp. utility	3,950	4,378	4,373	4,777
Year 2	V1	NDE1	YES	436	439	440	456
			NO	187	463	616	1353
			Net exp. utility	-253	28	178	914
	V1	DE1	YES	436	437	437	438
			NO	0	1	0	2
			Net exp. utility	-438	-436	-436	-435
	NV1	DE1	YES	436	437	437	438
			NO	0	48	41	194
			Net exp. utility	-437	-411	-395	-242
	NV1	NDE1	YES	436	438	440	457
			NO	1,470	1,837	3,039	4,755
			Net exp. utility	1,028	1,398	2,597	4,315

In approximately 21 per cent of the simulated decision outcomes, the net expected utility of vaccination was negative (see also the black line in Figure 4). It indicated that the DM has become nearly indifferent between both decision options. A less likely decision moment to be entered in year 2 was when DE_1 turned out to be present while V_1 was carried out. In that case, the optimum was not to vaccinate as immunity reduces the probability of re-infection to nearly zero and therefore the costs of vaccination of the herd can be saved. Based on the net expected utility of vaccination, the same holds for the situation with NV_1 with DE_1. The slightly higher income loss compared to the situation analysed previously is due to the fact that vaccination was not carried out in year 1 and hence the herd susceptibility was higher. The fourth decision moment in year 2 is with NV_1 and NDE_1 previously. Compared to year 1, probability of disease decreased resulting in lower net expected utility of vaccination. Nevertheless, vaccination of the herd was the best decision to make.

In scenario 2, when it was assumed that part of the heifers are retained for export, the DM did have an extra interest in vaccination since it guarantees that these heifers would be free of BTV-8 at time of exportation. Pointed out in Table 6, the additional interest was reflected in a larger net expected utility of vaccination in all situations compared to results for scenario 1, except for situations with DE_1.

Table 2-5: Overview of the decision outcomes for scenario 2, represented as income losses in Euros. The underlined vaccination decisions indicate the policy suggestion which is the optimal route when the full tree is run.

Decision moment	Events passed		Vaccinate?	Income losses			
				Min	Mode	Median	Max
Year 1	*NA*		<u>YES</u>	507	592	639	856
			NO	10,098	11,086	11,022	11,864
			Net exp. utility	9,431	10,252	10,372	11,274
Year 2	V_1	NDE_1	<u>YES</u>	506	555	584	813
			NO	465	1,039	1,455	3208
			Net exp. utility	-93	613	868	2511
	V_1	DE_1	YES	503	549	575	800
			NO	1	48	72	298
			Net exp. utility	-506	-502	-502	-499
	NV_1	DE_1	YES	504	548	575	804
			NO	6	124	172	652
			Net exp. utility	-504	-437	-411	-75
	NV_1	NDE_1	YES	507	552	584	814
			NO	3,386	5,797	6,958	10,765
			Net exp. utility	2,822	9,412	6,363	10,200

As a result, in the most likely entered decision moment in year 2 the net expected utility of vaccination ranged from €-93 to €2,511, with a median of €868. In 0.4% of the simulated decision outcomes, net expected utility of vaccination was negative. The likelihood that the DM repeated vaccination of the herd was thus much higher.

2.3.3 Risk aversion impact

Results so far represented a risk neutral DM, since all outputs were based on the EMV criterion. However, for many of the decision outcomes, risk aversion would not change the net expected utility of vaccination in such a way that the decision switched.

In scenario 1, there was one case where risk was important: the (most likely) decision moment in year 2, with V_1 and NDE_1 previously. For this case, it was already shown that the distributions of both decision options overlap, and also that the variation around the mean of the distribution associated with no vaccination was very large whereas it was the opposite for vaccination (Table 4). Small variation here indicates that only a small risk is present.

Figure 3 illustrates what happens for this situation when different risk tolerance levels are set. The distribution of the vaccination decision shifts gradually from the left to the right if less risk is tolerated, whereas the distribution of the no vaccination decision shifts considerably to the right. As a consequence, the net expected utility of vaccination – previously defined as the difference between both decision options – becomes proportionally more negative when the degree of risk aversion increases.

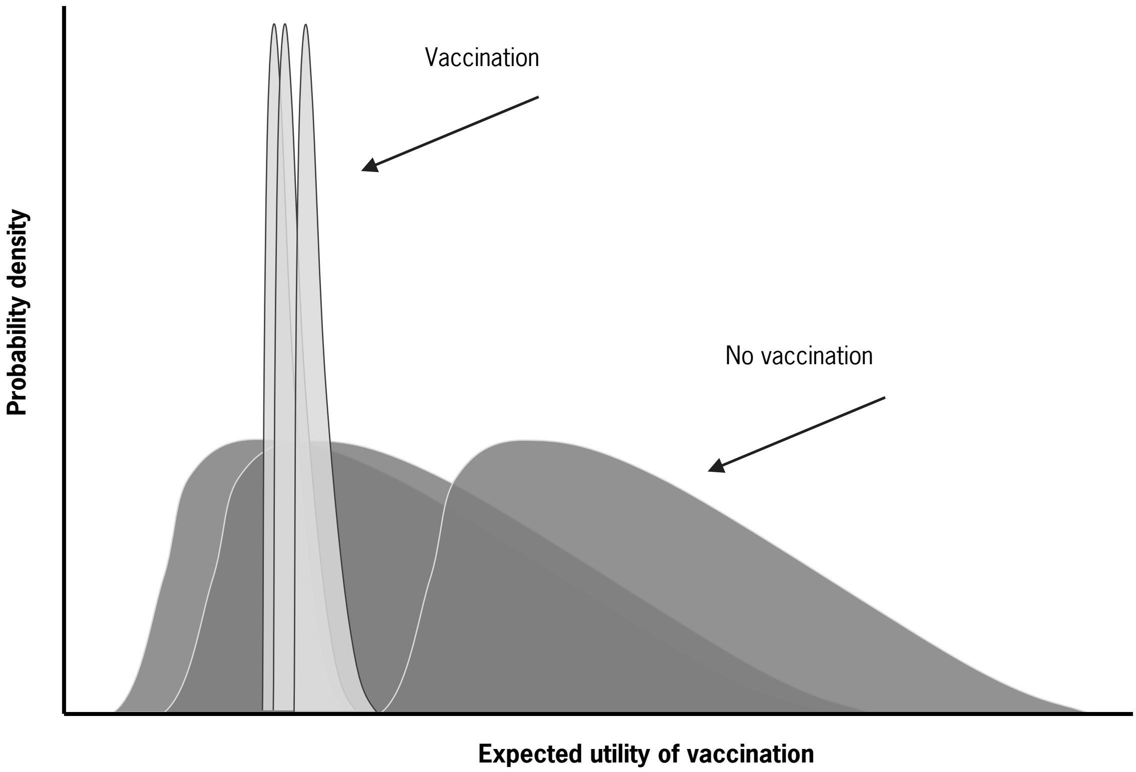

Figure 2-3: Graphical illustration of the effect of risk aversion on the decision outcomes for the situation in scenario 1 in year 2 with vaccination (V_1) and no disease effects (NDE_1) in year 1, with on the horizontal axis the expected utility from the decision taken, and on the vertical axis the probability density. For the vaccination decision, if less risk is tolerated, the expected utility doesn't increase so much; for the no vaccination decision, if less risk is tolerated, the expected utility increases considerably.

Table 7 shows the calculated certainty equivalents (CE) of the decision outcomes and the net expected utility of vaccination for different risk tolerance levels represented as income losses. As argued before, the risk associated with the decision not to vaccinate was valued much higher.

Table 2-6: Overview of the decision outcomes for different risk tolerance levels for the situation in scenario 1 in year 2, with vaccination (V_1) and no disease effects (NDE_1) in year 1, represented as income losses in Euros. The risk tolerance levels are: risk neutrality (R = inf), hardly risk averse (R = 30,000) and highly risk averse (R = 3,000).

Risk tolerance	Vaccinate?	Income losses			
		Min	Mode	Median	Max
	YES	436	439	440	456
R = inf	NO	187	463	616	1,353
	Net exp. utility	-253	28	178	914
	YES	436	440	441	458
R = 30000	NO	204	502	667	1,445
	Net exp. utility	-236	67	225	1,007
	YES	436	445	448	490
R = 3000	NO	478	1,067	1,351	2,431
	Net exp. utility	31	1,027	899	1,988

The implications for the net expected utility of vaccination are depicted in Figure 5. In this graph, the net expected utility of vaccination is depicted as a cumulative probability function for different levels of risk aversion. Based on the median, which in the graph equals the 0.5 cumulative probability value, the decision outcome was always to re-vaccinate in year 2.

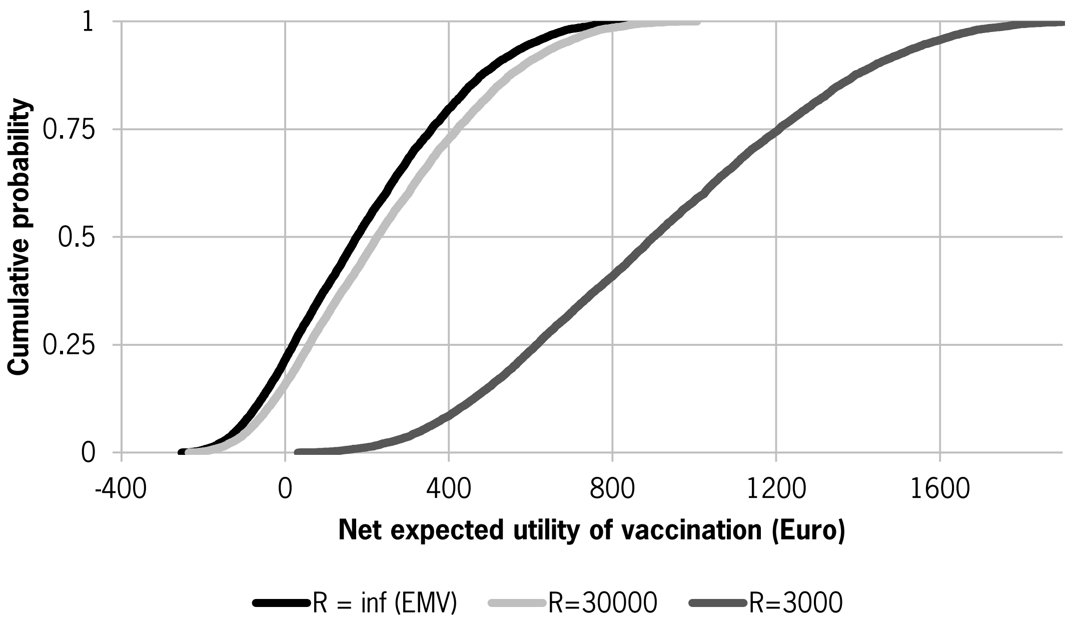

Figure 2-4: Graph of the net expected utility of vaccination for different risk tolerance levels R for the situation in scenario 1 in year 2 with vaccination and no disease effects in year 1, with on the horizontal axis the net expected utility, and on the vertica

However, when risk is considered, the risk attitude is important for the final outcome. In cases where risks would be ignored (R = inf) the cumulative probability function indicated that in approximately 21 per cent of the simulated decision outcomes, it was better not to vaccinate based on a negative net expected utility of vaccination. This percentage reduced to approximately 16 per cent for a hardly risk averse DM. The cumulative probability function corresponding with the highly risk averse DM was entirely positive.

In scenario 2, risk aversion did not change most of the outcomes so that another decision was taken. Only for the decision moment in year 2 with NV_1 and DE_1 previously, the outcome changed. In this case, with risk neutrality, the net expected utility of vaccination was negative with a median of €-411. (Table 6). With high risk aversion, the net expected utility of vaccination was generally positive. The cost of vaccination was compared with the small probability of disease and therewith the small probability of an export restriction. For a highly risk averse DM, this risk is highly valued and thus was vaccination preferred. However, it was not likely that the DM enters this decision moment in year 2, because in year 1 the most likely decision is to vaccinate.

2.3.4 Validation

As a sensitivity analysis, economic consequences derived from the deterministic model used in this study were replaced by those estimated by Santman-Berends (2011). According to this study, for a completely susceptible herd with 75 cows at the moment of introduction, the economic consequences were estimated to be €1,962, including costs of diagnostics, treatment and production losses. Economic consequence related to an export ban was not studied and thus remained as it was as in the original calculation.

Results can be categorized threefold. First, for decision outcomes after DE_1 occurred, the net expected utility did not change; the costs of vaccination of the herd can be saved after the herd is immunized. Second, for all except one decision outcomes after NDE_1 occurred, the net expected utility did considerably change in its magnitude but not in its direction (based on the median). Thus, the initial decision (to vaccinate) did not switch.

Third, the exception is the decision outcome in scenario 1 that was highlighted in section 3.3. The net expected utility ranged from €-368 to € 63 with a median of €-210 for a risk neutral DM. Risk aversion did not lead to a positive net expected utility (based on the median).

2.4 Discussion

The prime objective of this study was to assess the farmer's willingness to vaccinate against BTV-8 based on the net expected utility of vaccination. According to the results, the average Dutch dairy farmer is expected to be willing to vaccinate against BTV-8, except for situations where disease effects intermediately showed up. Heifer management is important; when heifers are reared for export, the overall net expected utility of vaccination is higher. The farmer's willingness to vaccinate in year 2 was surrounded with uncertainty.

Eradication of BTV-8 is most likely to happen when a large part of the national herd becomes immune through either vaccination or lifelong protection due to natural infection in a short period of time. Therefore, from a sectorial viewpoint, it is important that farmers collectively vaccinate to increase the likelihood of eradication. The main policy instrument used in 2008 was subsidization of the costs of vaccination. In 2009, subsidization stopped (Velthuis et al., 2011). Vaccination coverage in that year dropped to between 50 – 60% (Elbers et al., 2010). Dairy farmers who did not want to vaccinate and those in doubt about vaccination indicated that a subsidized campaign (similar to that of the previous year) along with disclosure of information about (1) the efficacy and safety of the vaccine and (2) the whys and wherefores of repeated vaccination could motivate them (Elbers et al., 2010). Reducing the costs of vaccination with subsidization can stimulate farmers, who perceive the chance of infection to be low, to revaccinate. The effects of disclosure of information as a policy instrument is not clear and is hardly studied within the field of economics of animal health. It might be that farmers interpret the information disclosed, e.g. with respect to the efficacy of the vaccine, and make decisions that are not optimal from a social point of view (Bennett, 2012).

Results of this paper suggest that when financial incentives are used as a policy instrument, a change of the subsidy schemes can be beneficial. Decision making in the control of animal disease epidemics is a dynamic and flexible process (Ge et al., 2007). The results show that the farmer is highly willing to vaccinate in year 1 whereas it becomes less likely that vaccination is repeated, assuming that the farmer act as a rational economic DM that maximizes expected utility. Validation of the decision outcomes, using results of Santman-Berends (2011), emphasized this. The reduced net expected utility from vaccination in year 2 must be seen in the light of the classical externality problem: despite the fact that BTV-8 is not contagious, the activity level of one farmer to mitigate the virus affects the situation of another farmer either positively or negatively. There are no incentives for one farmer to take costly actions that are only in favour of another farmer. At the same time disease eradication is only met when vaccination is collectively executed.

For this situation, risk aversion can have an effect given that the extra certainty about income is valued more by a risk averse farmer, but that might not be enough as the validation suggested. Besides, not all farmers can be expected to be risk averse. Therefore, if financial incentives are used, they could be better allocated to year 2 to increase the farmers' net expected utility of vaccination, to motivate farmers to re-vaccinate. Another possibility is to ask farmers to vaccinate their herd for two years, with the prospect of providing financial incentives over time.

The decision problem analysed is based on the BTV-8 epidemic circumstances of 2008, using an average Dutch dairy farm located in an area with susceptible herds. The results are not representative for other production systems, as the payoffs were calculated specifically for a dairy farm. Furthermore, as payoffs were determined deterministically, the average costs were always equal; and thus the effect of e.g. varying the herd (farm) size was not studied.

Data used for parameterizing the model were mainly based on historical data of the disease costs in 2006 and 2007 (Velthuis et al., 2010). Costs related to diagnosis and treatment were presumed to be still valid for the time period studied. For calculating the production losses, prices were updated for the time period studied and some of the epidemiological input were revised by the experts involved in this study when it was revealed that they had been overestimated (see Appendix I). The economic consequences of an export restriction for an individual farm were kept fixed over time; potential supply and demand effects in the markets for heifers and beef were outside the scope of this study.

The efficacy of the vaccine has a large influence on the probability of disease effects in the year vaccination takes place, but also for the year after. Vaccine manufacturers claimed at the start of the vaccination campaign that the BTV-8 vaccine would protect the animal for at least one year (Elbers et al., 2010). At that time this was the guiding thought among practitioners implying that they recommended re-vaccination to farmers. Hence in the model it was assumed that the efficacy of the initial vaccine somewhat continued, reflected in a lower probability of disease effects in year 2. Ex-post, however, it turned out that the vaccine protected cattle for at least three years (Oura et al., 2012). Would that have been known also by the farmer community, they would have decided not to re-vaccinate.

The decision problem presented in this study simulated a decision-making process in the middle of an epidemic situation. Farmers did not have experience in controlling BTV-8 because it was an emerging disease at that time. It is not entirely clear how aforementioned time and disease characteristics affect decision-making under uncertainty. Utility elicitation can only be done for a short period of time under a given set of circumstances and thus it matters at which point in time the decision problem is presented (Ngategize et al., 1986). For example, two studies about the voluntary participation of farmers in pre-epidemic animal disease insurances found diverse results. An empirical study by Ogurtsov et al. (2009) that looked into Dutch dairy farmers buying different categories of catastrophe insurance, reported that the impact of assumed risk aversion on buying insurance was not found for those related to insuring animal disease epidemics. The authors argued that it was hard for farmers to estimate the probability of occurrence of an outbreak and therefore they may underestimate potential risks. Niemi and Heikkilä (2011) who studied the impact of risk aversion and hypothetical disease outbreak characteristics on group participation in animal disease insurance concluded that farmers avoid (the present value of) premiums as they lack the incentives to participate before an outbreak occurs. Another study done by Rat-Aspert and Fourichon (2010) looked into the collective effectiveness of voluntary vaccination against a hypothetical endemic infectious disease. Their results suggest that voluntary vaccination cannot eradicate the modelled disease, and that risk aversion, as well as incentives, only results in a lower prevalence over time.

Both, results of aforementioned studies and the results of this study suggest that the moment of the decision, e.g., pre-epidemic versus the middle of an epidemic, and the characteristics of the disease problem are very important for the farmer's voluntary decision to cooperate in animal health programmes, assuming economic rational behaviour. In a study of Valeeva et al. (2011), it was found that Dutch pig fattening farmers perceive endemic diseases as operational risks whereas epidemic diseases are classified as catastrophic risks. Severity of disease was valued slightly but significantly more important for the latter than for the former. Important interactions between disease risk, the farmer's perception of that risk, his perceptions of available control options, and his actual practices might exist (Perry et al., 2001). Farmers may perceive the risk of an outbreak of an epidemic disease that has been absent for a long time be lower than the objective risk. The perceived risk may be higher than the objective risk if such an outbreak was recently reported in the farmers' vicinity (Ekboir, 1999). It might be that for emerging diseases, perception of disease risk of farmers, perhaps as well as for policy makers and veterinarians, is even higher.

Besides the perception of disease risks, farmers do also have perceptions about the efficacy of control options. An empirical study of Cross et al. (2009) indicated divergent efficacy beliefs on vaccination as a mitigation strategy for controlling BTV-8 amongst Scottish and Wales's farmers, but also amongst veterinarians. In this study, it was assumed that the DM perceives the probabilities as they have been estimated by experts ex-post (Hardaker and Lien, 2010). The underlying assumption here was that the DM had perfect information. An interesting avenue for future research is to empirically assess a farmer's perceived costs, benefits and risks and incorporate those results to the model to see if their own judgement change the output. Besides, this decision model can function as a basic framework to study farmer's decision-making related to other animal diseases.

Finally, it is agreed with Edwards-Jones (2006) that modelling farmers' willingness to vaccinate against BTV-8 involves more than standard economic theory; insights from other disciplines such as sociology and psychology are welcomed and need to be taken into account in future research.

2.5 Conclusions

Based on the net expected utility of vaccination, the average Dutch dairy farmer is expected to be willing to vaccinate against BTV-8 in the first year, it declines thereafter as a result of less expected costs of a continued outbreak. A risk averse farmer in this respect is more likely to continue vaccination.

Farmers who export heifers have a higher willingness to vaccinate.

A policy implication of this study is that for an effective allocation, financial incentives can be adjusted to the willingness to vaccinate over time.

Appendix

Below a detailed explanation of the cost calculations is given for (1) the total costs of vaccination and (2) the total loss from the BTV-8 epidemic for an individual (average) dairy farm. First the algebraic formulae are given. The full parameterization is summarized in Appendix Table.

(1)

$V = 2 \times (cf + hr \times du + (hs + hs \times rr \times ca) \times (vc + dm + rc))$

$du = 10 + 0.5 \times (hs + (hs \times rr \times ca)),$

$V_{exp} = 2 \times (cf + hr \times du + (hs + hs \times yr + \left(hs - (hs \times rr)\right) \times \frac{365}{ci} \times 0.5 \times (1 - dr) \times ca) \times (vc + dm + rc))$

$du = 10 + 0.5 \times (hs + hs \times rr + (hs - (hs \times rr)) \times (365/ci) \times 0{,}5 \times (1 - dr) \times ca)$

(2)

$L = (DC + TC + PL) + EXR$

$DC = cf + 0.5hr$

$TC = hs \times \frac{MBR}{100} \times rp \times \left([pt_{pk} \times price_{pk} + [pt_{ab} \times price_{ab} + [pt_{treated} \times price_{mt}\right)$

$PL = MT + EC + MP + WL + NG + PG + AB + SB$

$$MT = \frac{MTR}{100} \times rp \times \ hs \times (pv + sv + rc)$$

$$EC = \ pt_{ec} \times \frac{MBR}{100} \times rp \times \ hs \times pv$$

$$MP = \ \frac{MBR}{100} \times rp \times \ hs \times amp \times rmp \times 0.5dd \times vm$$

$WL = \ hs \times pt\_pl \times (ef_{wl} - fr_{wl})$

$NG = \ hs \times pt_{ng} \times (pv + price_{calf} - fh_{calf} - \mathit{\Delta} sv)$

$PG = \ hs \times pt_{pg} \times (ai2 + \Delta ci1)$

$AB = \ hs \times pt_{ab} \times (ai1 + AI2 + \Delta ci6)$

$SB = \ hs \times pt_{sb} \times (price_{calf} - fh_{calf})$

$EXR = (hs - hs \times rr) \times \frac{365}{ci} \times 0.5 \times (1 - dr) \times ev_h - sv_h$

Appendix table A2.1: Description of the input parameters used for calculating the economic consequences of vaccination against and losses from BTV-8 for the average Dutch dairy farm in 2008.

Variable	Description	Unit	Input parameter	Source
cf	Call-out fee veterinarian	euro/visit	20.58	Velthuis et al., 2011
hr	Hourly rate veterinarian	euro/hour	116.17	Velthuis et al., 2011
hs	Average herd size	# dairy cows	76	LEI/CBS, 2008
rr	Replacement rate	%	28	(Mohd Nor et al., 2013)
dr	Drop-out rate	%	8	(Mohd Nor et al., 2013)
ca	Calving age	years	2.25	(Mohd Nor et al., 2014)
vc	Vaccine costs	euro/dosage	0.40	Velthuis et al., 2011
dm	Dispense material costs	euro/dosage	0.02	Velthuis et al., 2011
rc	Registration costs	euro/dosage	0.05	Velthuis et al., 2011
$MBR/100$	Morbidity rate	animals/100 animal months	5.6	Elbers et al., 2009
rp	Risk period	months	6	Elbers et al., 2009
pt_{pk}	Proportion diseased animals treated with pain killers	%	50	Velthuis et al., 2010
$price_{pk}$	Price pain killer	euro/animal	15	Velthuis et al., 2010
pt_{ab}	Proportion diseased animals treated with antibiotics	%	50	Velthuis et al., 2010
$price_{ab}$	Price antibiotics	euro/animal	50	Velthuis et al., 2010
$pt_{treated}$	Proportion diseased animals treated in general	%	50	Velthuis et al., 2010
$price_{mt}$	Price materials	euro/animal	0.75	Velthuis et al., 2010
$MTR/100$	Mortality rate	animals/100 animal months	0.2	Elbers et al., 2009
pv	Production value	euro/animal	480	Average, based on Houben et al., 1994, updated by van der Walle, 2004
sv	Slaughter value	euro/animal	684.75	LEI/CBS, 2008
rc	Rendering costs	euro/animal	26.02	Velthuis et al., 2010
pt_{ec}	Proportion diseased animals earlier culled	%	0	Authors' expertise
amp	Average milk production	liters/animal	26.7	(CRV, 2008)
rmp	Reduction in milk production	%	20	Velthuis et al., 2010
dd	Days diseased	days	18	Elbers et al., 2008b
vm	Value of the milk (variable costs)	euro/liter	0.06	(KWIN, 2006)
pt_{pl}	Proportion diseased animals that exhibit weight loss	%	7	Velthuis et al., 2010
ef_{wl}	Extra feed costs related to weight loss	euro/animal	5.60	Velthuis et al., 2010
fr_{wl}	Drop in feed intake related to weight loss	euro/animal	2.00	Velthuis et al., 2010
pt_{ng}	Proportion diseased animals that have no gestation	%	5	Revised by experts
$price_{calf}$	Lost value of a calf	euro/animal	163.06	Velthuis et al., 2010
fh_{calf}	Costs of feed and housing	euro/animal	3.57	Velthuis et al., 2010
Δsv	Increased slaughter value	euro/animal	45.80	Velthuis et al., 2010
pt_{pg}	Proportion diseased animals that have postponed gestation	%	16.6	Authors' expertise
$ai2$	Costs of an extra artificial insemination	euro/animal	13.85	KWIN, 2006
$\Delta ci1$	Loss due to extended calving interval of 1 cycle	euro/animal	9	Velthuis et al., 2010
pt_{ab}	Proportion diseased animals that have an abortion	%	6.2	Velthuis et al., 2010
$ai1$	Costs of the first artificial insemination	euro/animal	23.75	KWIN, 2006
$\Delta ci6$	Loss due to extended calving interval of 6 cycles	euro/animal	101.90	Velthuis et al., 2010
pt_{sb}	Proportion diseased animals that have a stillbirth	%	0.4	Velthuis et al., 2010/Rendac.nl
ev_h	Export value heifer	euro/animal	957.50	LEI
sv_h	Slaughter value heifer	euro/animal	647.40	LEI

Chapter 3

Using farmers' attitude and social pressures to design voluntary bluetongue vaccination strategies

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Abstract

Understanding the context and drivers of farmers' decision-making is critical to designing successful voluntary disease control interventions. This study uses a questionnaire based on the reasoned action approach framework to assess the determinants of farmers' intention to participate in a hypothetical reactive vaccination scheme against bluetongue. Results suggest that farmers' attitude and social pressures best explained intention. A mix of policy instruments can be used in a complementary way to motivate voluntary vaccination based on the finding that participation is influenced by both internal and external motivation. Next to informational and incentive-based instruments, social pressures, which stem from different type of perceived norms, can spur farmers' vaccination behaviour and serve as catalysts in voluntary vaccination schemes.

Keywords

farmers, decision-making, attitude, social pressures, disease control, bluetongue, voluntary vaccination, policy instruments

3.1 Introduction

Bluetongue (BT) is a World Organization for Animal Health (OIE)-listed animal disease. An outbreak of an OIE listed disease has major implications for livestock production, policy and trade in the country or region affected (Burrell, 2002). All these impacts were experienced during the bluetongue virus serotype 8 (BTV-8) epidemic from 2006 – 2009 in the Netherlands. The virus caused clinical disease in ruminants, thereby affecting dairy as well as other farm types in cattle, sheep and goat sectors (see Elbers et al. (2008a) for an overview). Financial consequences of the epidemic in 2006 and 2007 in the Netherlands have been estimated around 200 million Euros, of which about 140 million Euros relating to the dairy cow sector (Velthuis et al., 2010).

A reactive vaccination programme at transnational level was adopted in 2008 since the direct control measures and the ban of animal movements failed to stop the spread. The Dutch government offered farmers a vaccination scheme on the basis of voluntary participation with subsidy as a financial, incentive-based policy instrument. It fits in with a neoliberal governance style of cost and responsibility sharing (e.g. Maye et al., 2014) and is based on economic theory postulating that self-regulation may result in successful interventions at lower public cost (e.g. Oude Lansink, 2011). The *ex-ante* transaction costs of lobbying and legislation and *ex-post* transaction costs of surveillance and enforcement are minimized (Furubotn and Richter, 1998).

Since the implementation of the vaccination scheme, only a few Dutch farms got infected in 2008 and 2009. However, it is difficult to judge *ex-post* whether the voluntary approach was a success or a failure while many farms were already immunized via natural infection (Wilson and Mellor, 2009), which in combination with a low uptake could already be sufficient to control the spread. Actual uptake by dairy farmers have been estimated at 71% in 2008 (with subsidy) (Elbers et al., 2010).

After the BTV-8 epidemic, Elbers et al. (2010), in an exploratory survey among Dutch farmers, showed that (1) prevention of production losses and (2) subsidization of vaccination were perceived as the main motives to vaccinate against BT. Other important motives mentioned were: (3) welfare concerns, (4) contribution to the eradication campaign and (5) recommendation by the practitioner.

To understand and predict individual vaccination decisions, rational choice models, i.e. expected utility theory (EUT) models are often applied (Hardaker and Lien, 2010; Rat-Aspert and Fourichon, 2010; Sok et al., 2014). In these models, the motives 1 and 2 are considered. It is often argued that governments should increase the expected utility (profits) by utilizing financial, incentive-based policy instruments to make voluntary disease control interventions effective.

Considering the motives 3 – 5 however, it might be that additional self-regulatory or motivational mechanisms exist that drive the decision to vaccinate, which cannot directly be inferred from rational choice models. Some of these mechanisms are embedded in different types of norms. Social psychological decision models emphasize the effect of social pressures on decision-making, such as the reasoned action approach (RAA) (Fishbein and Ajzen, 2010). The RAA predicts that a given behaviour is determined by the strength of a person's intention to perform that behaviour. The intention is a function of three social-psychological constructs: attitude, perceived norms and perceived behavioural control. Nowadays different dimensions are captured within these constructs, also prompted through the use of multivariate statistical techniques (Thompson, 2004). Within attitude, an instrumental and experiential dimension are distinguished. Factors considered in a typical EUT model are similar to this instrumental dimension. Within perceived norm, an injunctive and descriptive dimension are distinguished. Within perceived behavioural control, a capacity and an autonomy dimension are distinguished (see Fishbein and Ajzen (2010) for an overview). In this study, only the construct of perceived norms is disentangled into an injunctive and descriptive dimension to investigate in more detail the social pressures operating on farmers.

Next to information and incentive-based instruments is the effectiveness of disease control interventions also dependent on reflecting, re-enforcing and shaping attitudes and norms within a community (Collier et al., 2010). Therefore an understanding of which of these constructs drive farmers' compliance with a policy intervention is critical for an efficient and effective design. The aim of this research is to assess which of the socio-psychological constructs and underlying dimensions drive farmers' intention to participate in a hypothetical reactive vaccination scheme against BT.

3.2 Material and methods

3.2.1 Framework and statistical method

The RAA model identifies the social-psychological constructs that may influence intention to carry out particular behaviours, so that statistical modelling can be used to estimate the nature and significance of these relationships.

The model can mathematically be represented as follows:

$$B \sim I = f(A, PN, PBC), \tag{1}$$

where $PN = f(N_I, N_D)$, (2)

B given behaviour

I intention to perform the behaviour

A attitude – the farmer's positive or negative evaluation of performing that behaviour

PN perceived norms – the social pressures one feels to perform that behaviour

N_I injunctive norm – the perceptions of what referents think he or she should do

N_D descriptive norm – the perceived behaviour of others (farmers)

PBC perceived behavioural control – the perceived own capability to perform that behaviour.

In this study, structural equation modelling (SEM) was used to estimate the entire RAA as a set of simultaneous equations. It models correlational and causal relationships among constructs and corrects for measurement errors of the observed variables that represent these constructs in the estimation procedure. A construct is a latent variable that can be defined in conceptual terms but cannot directly be measured or be measured without error. Therefore, a construct is represented by multiple variables that, in combination, give a reasonably accurate measure of the construct using factor analytic approaches (Hair et al., 2010).

The commonly applied two-step modelling approach in SEM, developed by Anderson and Gerbing (1988), was used. First step was to estimate a measurement model in which the variables were assigned to their constructs, using confirmatory factor analysis. Thus, based on the RAA model, it was *a priori* specified which variables make up which of the five constructs. Based on tests assessing the score reliability, score validity and overall model fit (e.g. see Fornell and Larcker, 1981), the measurement model was evaluated on its specification and consistency with the data.

The second step was to estimate a structural model in which the causal relationships were tested to investigate the impact of the exogenous constructs attitude, injunctive norm, descriptive norm and perceived behavioural control on the endogenous construct intention. As constructs are often highly correlated, different model specifications were run to assess the presence of multicollinearity.

3.2.2 Questionnaire and sample

In Table 1 a description of the variables measured is given, with these elements being based on the standard questionnaire format provided by Fishbein and Ajzen (2010). In defining the action that respondents were to undertake (or rather, express their intention to undertake) Ajzen's TACT principle has been used, with actions defined in terms of target, action, context and time. For example, 'If bluetongue (target) were to occur in the environment (context) this year (time), and a voluntary vaccination programme was to be announced (context), I am going to vaccinate my herd preventively (action). All questions were preceded with the phrase: "If bluetongue were to occur in the environment this year", and for the questions related to the constructs perceived behavioural control and intention the words "and a voluntary vaccination programme was to be announced" were added to emphasize the voluntary nature of the vaccination scheme.

A 5-points semantic differential scale with five different bipolar adjective pairs (e.g. unsatisfying and satisfying) was used to measure attitude. The other variables were measured with 5-point bipolar Likert-type scales with endpoints 'disagree' to 'agree'.

A random sample of 1,500 Dutch dairy farms was drawn from the National Cattle Identification and Registration Database. The sample was restricted to farms with a herd size of at least 40 dairy cows, which is about 80 to 85 per cent of the whole dairy farm population (LEI, 2016). These are more likely to be professional dairy farmers rather than hobby farmers. The latter type of farmers were excluded because it was felt that their decision-making process for vaccination decisions, in the face of a threat of a BT infection, could be made in a very different decision context (e.g. Gethmann et al., 2015).

Table 3-1: Description of the variables for representing the constructs in the SEM.

Construct and variable		Description of the statement	
Attitude	a_1	Preventive vaccination of my herd is …	… unsatisfying – satisfying[a]
	a_2		… disadvantageous – advantageous[b*]
	a_3		… necessary – unnecessary[b]
	a_4		… unimportant – important[b]
	a_5		… acceptable – unacceptable[a*]
Injunctive norm	ni_1	People who have something to do with my farm expect me to vaccinate my herd preventively.	
	ni_2	People in the industry whose opinions I value would approve of me vaccinating my herd preventively.	
	ni_3	People who are important to me think that I should vaccinate my herd preventively.	
Descriptive norm	nd_1	Farmers like me are going to vaccinate their herd preventively.	
Perceived (beh.) control	pbc_1	I do have the possibility to vaccine my herd preventively.[c]	
	pbc_2	I could vaccinate my herd preventively, if I wanted to.[c]	
	pbc_3	It is up to me whether I vaccinate my herd preventively.[d]	
Intention	i_1	I am going to vaccinate my herd preventively.	
	i_2	I do want to vaccinate my herd preventively.	
	i_3	I am willing to vaccinate my herd preventively.	

[a] Experiential dimension
[b] Instrumental dimension
[c] Capacity dimension
[d] Autonomy dimension.
* These variables were reversely recoded for the statistical analysis.

The questionnaire[1] was pre-tested on two dairy farmers. The final, revised, questionnaire was sent out in January 2014, along with a pre-paid return envelope and an accompanying letter in which the relevance of the research was set out. Farmers were offered two possibilities to fill in the questionnaire: using the paper copy, or on-line. The letter ended with a guarantee of anonymity of responses and the offer of a financial incentive to take part: i.e. a 10 per cent chance of winning a gift coupon of € 25. After 4 weeks, a reminder was sent to all farmers in the sample. The final response, the 415th, was returned March, resulting in a response rate of 28 per cent. About one sixth of the returned questionnaires were filled out on-line. Observations with missing values were excluded from the statistical analysis, resulting in an effective sample size of 357.

[1] The questionnaire is available upon request.

3.3 Results

3.3.1 Descriptive statistics

Regarding respondents' attitude, mean rank scores of the observed variables ($a_1 - a_5$) indicated a fairly positive evaluation of the outcomes of the behaviour (3.57 – 3.86) (Table 2). Correlations among variables for attitude were high (all within-construct correlations are marked bold). Correlations between variables for attitude and intention were also high.

Regarding respondents' perceived norms, mean rank scores of the variables were around average (2.99 – 3.43). Correlations among variables for injunctive norm were high. The variable ni_2 based on the question "people in the industry whose opinion I value" had the highest mean rank but at the same time was only weakly correlated with the intention variables. The other two variables for injunctive norm correlated highly with those of intention, attitude and descriptive norm.

Table 3-2: Sample correlation matrix with means , standard deviations of the variables and Cronbach's alpha values of the constructs.

Variable		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	$\propto_c$
1.	a_1	1															.90
2.	a_2	.72	1														
3.	a_3	.67	.59	1													
4.	a_4	.76	.69	.81	1												
5.	a_5	.59	.49	.58	.59	1											
6.	ni_1	.43	.43	.46	.48	.36	1										.80
7.	ni_2	.23	.27	.27	.30	.39	.58	1									
8.	ni_3	.41	.40	.45	.48	.39	.65	.49	1								
9.	nd_1	.30	.26	.21	.28	.25	.44	.26	.33	1							-
10.	pbc_1	.24	.27	.21	.29	.35	.20	.29	.19	.04	1						.73
11.	pbc_2	.27	.30	.23	.29	.32	.16	.23	.20	.09	.75	1					
12.	pbc_3	-.08	.00	.00	.00	.04	.00	.01	.00	-.05	.35	.31	1				
13.	i_1	.66	.56	.58	.68	.51	.50	.26	.51	.35	.29	.28	.02	1			.94
14.	i_2	.64	.54	.58	.65	.51	.51	.28	.50	.35	.30	.30	.03	.92	1		
15.	i_3	.60	.54	.57	.61	.58	.45	.32	.48	.31	.31	.31	.02	.81	.81	1	
Mean		3.64	3.57	3.57	3.75	3.86	2.99	3.43	3.03	3.27	3.95	4.08	4.18	3.22	3.11	3.43	
Std. Error		1.13	1.02	1.12	1.08	1.06	1.24	1.16	1.18	1.00	0.99	.95	1.04	1.26	1.24	1.22	

Regarding respondents perceived behavioural control, mean rank scores of the variables were just below or above 4 (3.95 – 4.18). The scores indicated that, on average, farmers were capable of performing vaccination against BT. The variable pbc_3, representing the autonomy dimension within perceived behavioural control, had the highest rank (4.18) but had modest correlations with the other variables within perceived behavioural control and at the same time was not correlated with all other variables, including those of intention.

Regarding respondents' intention, mean rank scores were slightly above average (3.11 – 3.43). The variable i_3 had the highest score (3.43), most likely because the phrase used – I'm willing to – was the least powerful expression to measure intention. Correlations among variables for intention were very high.

Correlations among observed variables for each construct were internally consistent given the $\propto_C$ values (Table 2). The $\propto_C$ for the constructs attitude and intention were "excellent", for injunctive norm "very good" and for perceived behavioural control "adequate" (Kline, 2011). For descriptive norm there was only one observed variable, hence the score reliability cannot be calculated for this construct.

3.3.2 SEM estimations

The evaluation of the measurement model resulted in a respecification. The main issue here was that the variable pbc_3 (representing the autonomy dimension) was removed from the model because of low score validity, and thus only the capacity dimension remained with perceived behavioural control.

Figure 1 shows the estimated causal relationships, the extent to which the exogenous constructs attitude, injunctive norm, descriptive norm and perceived behavioural control impact upon the endogenous construct intention. All exogenous constructs inserted were allowed to correlate. The highest causal relationship was that of attitude on intention, while holding all other constructs constant. These results at first sight suggest that, for the vaccination behaviour, attitude is the main determinant of intention.

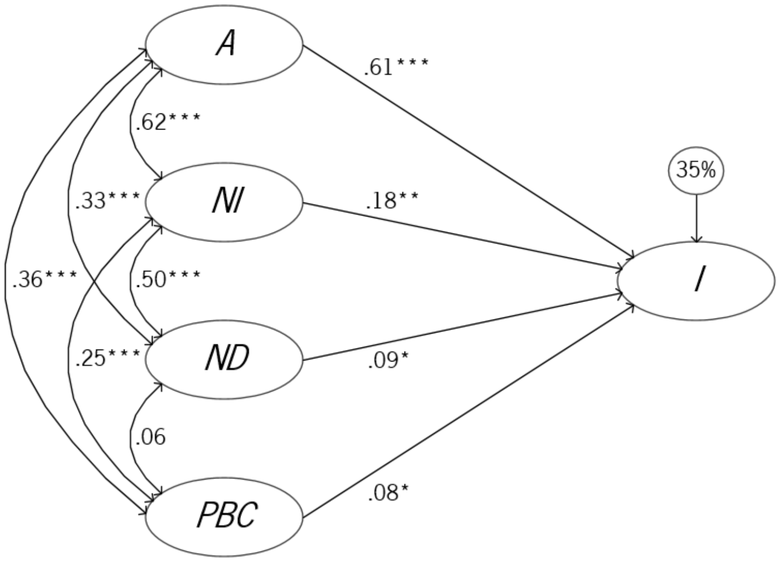

Figure 3-1: Structural model estimation, where an ellipse represents a construct, a circle an error term, a straight arrow a dependence relationship and a curved arrow a correlational relationship. The number of asterisks denote the significance level where *, ** and * are at 0.001 (highly), 0.01 (moderately) and 0.10 (somewhat) respectively.**

Given the discrepancy between beta's on and intercorrelations between constructs, results also suggested shared variance (multicollinearity) being present among exogenous constructs. Table 3 shows different model specifications that were run to show where the multicollinearity was present. The main source of collinearity was found between the constructs attitude and injunctive norm when explaining intention. In model specifications A and B, the beta's of both constructs were separately estimated, while in model specification C they were jointly estimated. In the latter specification, the beta of injunctive norm got a much lower regression weight due to the high correlation with attitude. Therefore, in addition to attitude, injunctive norm was an important determinant of intention.

Table 3-3: Different structural model specifications to show the presence of multicollinearity among constructs.

Model spec.	Exogenous constructs inserted	Beta estimates of:				R^2
		1. Attitude	2. Injunctive norm	3. Descriptive norm	4. Perceived beh. control	
A	1.	0.77				0.59
B	2.		0.61			0.37
C	1. and 2.	0.62	0.23			0.62
D	3.			0.38		0.14
E	2. and 3.		0.56	0.10		0.37
F	4.				0.37	0.13
G	1., 2., 3. and 4.	0.61	0.18	0.09	0.08	0.65

A smaller source of collinearity was found between both normative constructs when explaining intention. In model specifications B and D, the beta's of both normative constructs were separately estimated, while in model specification E they were jointly estimated. In the latter specification, the beta of descriptive norm got a much lower regression weight due to the high correlation with injunctive norm. Therefore, in addition to injunctive norm also descriptive norm had some impact upon intention. Or put differently, within the perceived norm construct, injunctive norm was more important than descriptive norm.

3.4 Discussion

Results of this study suggest that attitudinal considerations outweigh normative and control considerations as causal factors influencing intention to vaccinate against BT. Thus, farmers who exhibited a positive intention to vaccinate evaluated that behaviour positively, and vice versa. Although attitude turned out to be the main determinant of intention, results indicated that social pressures influenced intention formation as well.

Three main types of policy instruments are commonly distinguished: financial, incentive-based (*carrots*), regulative (*sticks*), and informational (*promises* or *sermons*) instruments (Rothschild, 1999; Bemelmans-Videc et al., 2011). Traditionally, the focus has been on financial and regulative instruments (Collier et al., 2010). The first and third type of policy instrument can be used to motivate voluntary participation where carrots are 'external motivators' and promises 'internal motivators'. Both these instruments were used in the past BT vaccination strategy in 2008 (Ministry of Economic Affairs, 2008).

Since attitude is the main determinant of intention and farmers, on average, expressed a fairly positive evaluation of the outcomes of the behaviour, an obvious type of policy instrument to stimulate the vaccination uptake are informational instruments that can increase the internal motivation by reasoned opinions. One should consider that information is more likely accepted if there is a credible communicator, a high level of 'similarity' between the audience and communicator and both the message and communicator must be perceived as trustworthy (Petty and Cacioppo, 1996).

Subsidization as a financial, incentive-based instrument, is an external motivator to encourage participation by making herd vaccination cheaper. Its effect on farmers' vaccination behaviour can be heterogeneous as different crowding effects can occur. Subsidization can strengthen (crowding-in) but also weaken (crowding-out) the internal motivation (Frey, 1993; Deci et al., 1999) and norms that induce behaviour externally (Bowles and Polanía-Reyes, 2012; Kuhfuss et al., 2015). It is important to take into account that different groups of farmers base their participation decisions on different considerations, and therefore a mix of instruments is required to maximize the uptake (Barnes et al., 2015).

The model of individual decision-making utilized in this paper originates from social psychology and is not a rational choice model. The RAA gives more weight to social aspects of decision-making. Results show that, for the BT vaccination decision problem, farmers' decision-making is affected by social pressures. Thus, farmers in this respect do not act as autonomous actors who can be encouraged to participate only by providing information or incentives, but they are influenced by what referents think (injunctive norm) and what the expected behaviour of other farmers will be (descriptive norm).

Given that these social interactions among farmers and other referents about vaccination decisions exist, motivational mechanisms, such as peer group pressure, can be actively used as a fourth type of policy instrument to motivate participation (Leeuwis, 2007; Collier et al., 2010). Social pressures might take the role of a 'catalyst' among the mix of policy instruments used in BT vaccination strategies based on voluntary participation, and leverage the (cost-)effectiveness and efficiency of such interventions.

Intervention design can be further supported by empirically analyzing the indirect measures, i.e. looking at which underlying beliefs explain each construct (Sok et al., 2015). Studying indirect measures is very relevant as they can help understanding what exactly drives the behaviour (Montaño and Kasprzyk, 2008). Attitudinal and normative beliefs are of most interest since this analysis showed that the behaviour is driven by attitudinal considerations and injunctive and to a lesser extent descriptive norms. Moreover, the heterogeneity in farmers' beliefs can be mapped out with behavioural concepts, such as perceived risk and personality traits, and with differences in farming structures (Sok et al., 2016a).

In conclusion, it has been shown that farmers' attitude and social pressures best explained intention to vaccinate against BT. Informational policy instruments are used for motivating farmers' whose attitude is favourable; they can be motivated internally by reasoned opinions. Incentive-based policy instruments are used for motivating farmers externally by financial compensation. The effect of these subsidies on vaccination behaviour is likely heterogeneous and for each farmer not necessarily positive. Next to informational and incentive-based instruments, social pressures, which stem from different type of perceived norms, can spur farmers' vaccination behaviour and serve as catalysts in voluntary vaccination schemes.

Chapter 4

Farmers' beliefs and voluntary vaccination schemes: bluetongue in Dutch dairy cattle

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Abstract

This research utilizes the reasoned action approach framework to study which beliefs drive the intention of farmers to participate in a voluntary vaccination scheme against bluetongue. Knowing the driving beliefs can help in selecting an appropriate mix of policy instruments to enhance the participation rate and thereby improve the cost-effectiveness and efficiency of voluntary vaccination strategies. Results are used to evaluate the policy instruments used by the Dutch government in their 2008 vaccination strategy (communicative intervention and vaccine subsidization). The paper posits that social interaction mechanisms, such as peer group pressure, might advance the design of voluntary vaccination strategies.

Keywords

farmers, decision-making, beliefs, disease control, bluetongue, voluntary schemes, policy instruments

4.1 Introduction

Voluntary schemes are increasingly used in the governance of a secure and safe supply of food. For many issues, such as the veterinary and (phyto)sanitary safety, the governance is shifting in the direction of a more neoliberal model of cost and responsibility sharing (e.g. Enticott et al., 2014; Maye et al., 2014). Economic theory postulates that self-regulation may result in successful interventions at lower public cost (Oude Lansink, 2011). The *ex-ante* transaction costs of lobbying and legislation and *ex-post* transaction costs of surveillance and enforcement are minimized (Furubotn and Richter, 1998)

Regarding veterinary safety, governments worldwide agree on controlling animal diseases listed by the World Organisation of Animal Health (OIE) (OIE, 2017). In 2006, the Netherlands was struck by an introduction of bluetongue (BT), one of such OIE-listed diseases. Given her international responsibilities, the Dutch Ministry installed a package of disease prevention and control measures appropriate for BT (European Council, 2000; European Council, 2007). A mass transnational vaccination scheme with a vaccine made available from Spring 2008 onwards, was needed to control the disease (Velthuis et al., 2010; Sok et al., 2014).

Most European member states opted for a mandatory vaccination scheme, whereas the Netherlands, amongst a few others, opted for a voluntary approach. Two types of policy instruments were deployed to stimulate voluntary participation by farmers. A communicative intervention was implemented in which the Ministry as well as farmer organizations conveyed written or oral recommendations to motivate farmers intrinsically to vaccinate their cattle. Subsidization of the vaccination costs as an extrinsic motivator was another policy instrument put in place (Ministry of Economic Affairs, 2008).

The vaccination scheme, together with the standard prevention and control measures at EU level, was successful as the total number of reported outbreaks in the EU dropped from 45,000 in 2008 to 1,118 in 2009, to 176 in 2010, and finally to 39 in 2011 (IFAH, 2012). In the Netherlands, only 66 outbreaks were reported in 2008 compared to more than 6,500 in 2007 (Elbers et al., 2009b). Accordingly, the voluntary approach was sufficiently effective in controlling the spread from an epidemiological viewpoint. However, it must be noted that the average seroprevalence of antibodies against the BT virus among dairy cattle was already 68 per cent before the vaccination scheme started (Ministry of Economic Affairs, 2008) while it was estimated that approximately 80 per cent of livestock with protecting antibodies – required either by infection or immunization – was probably needed to prevent between-herd transmission (de Koeijer et al., 2011).

The epidemiological effectiveness of the voluntary approach depends on the level of participation of farmers in the vaccination scheme. The higher the level of participation, the more likely it becomes that the necessary level of immunological protection is reached that is required to disrupt the epidemic spread. As a consequence, also the cost effectiveness (control of the spread of the disease at the lowest costs possible) and the overall efficiency (costs of the vaccination scheme in relation to the benefits) will depend on the participation of farmers. For the past Dutch BT vaccination scheme, the mean level of participation among cattle farmers in 2008 was estimated at 71 per cent and at 57 per cent in 2009 (Elbers et al., 2010).

An exploratory survey among farmers showed that motivation to participate in a voluntary vaccination scheme against BT was driven by economic objectives but also by social-psychological objectives like animal welfare considerations and the perceived need to make a contribution to the eradication campaign (Elbers et al., 2010); these objectives relate to beliefs of farmers. Knowing which beliefs of farmers drive their decision to participate in a voluntary vaccination scheme is important as it can help understanding what kind of policy instruments most likely enhance the level of participation and thereby improve the (cost-)effectiveness and efficiency of voluntary vaccination strategies.

The main contribution of this paper is exploring farmers' beliefs on this subject, as to date they are not well-understood. This study utilizes the reasoned action approach (RAA, Fishbein and Ajzen, 2010). RAA decomposes beliefs into attitudinal, normative and control beliefs. Results are used to evaluate the Netherlands' past BT vaccination strategy and to provide insights that can be used to designing future voluntary vaccination strategies.

4.2 Framework

Figure 1 presents the conceptual framework based on the reasoned action approach that is used in this paper for analyzing farmers' beliefs. The RAA predicts that a given behaviour (B) is determined by the intention (I) to perform the behaviour. I, in turn, is directly explained by four main psychological constructs: attitude (A), the farmers' positive or negative evaluation of performing that behaviour; perceived norms (PN), the social pressures famers perceive to perform that behaviour; and perceived behavioural control (PBC), the perceived own capability to perform that behaviour. Within PN, a distinction is made between injunctive norms (N_I), the perceptions of what referents think one should do; and descriptive norms (N_D), the perceived behaviour of others (farmers). All direct measures explaining I, in turn, are explained by underlying beliefs, which are the indirect measures explaining I.

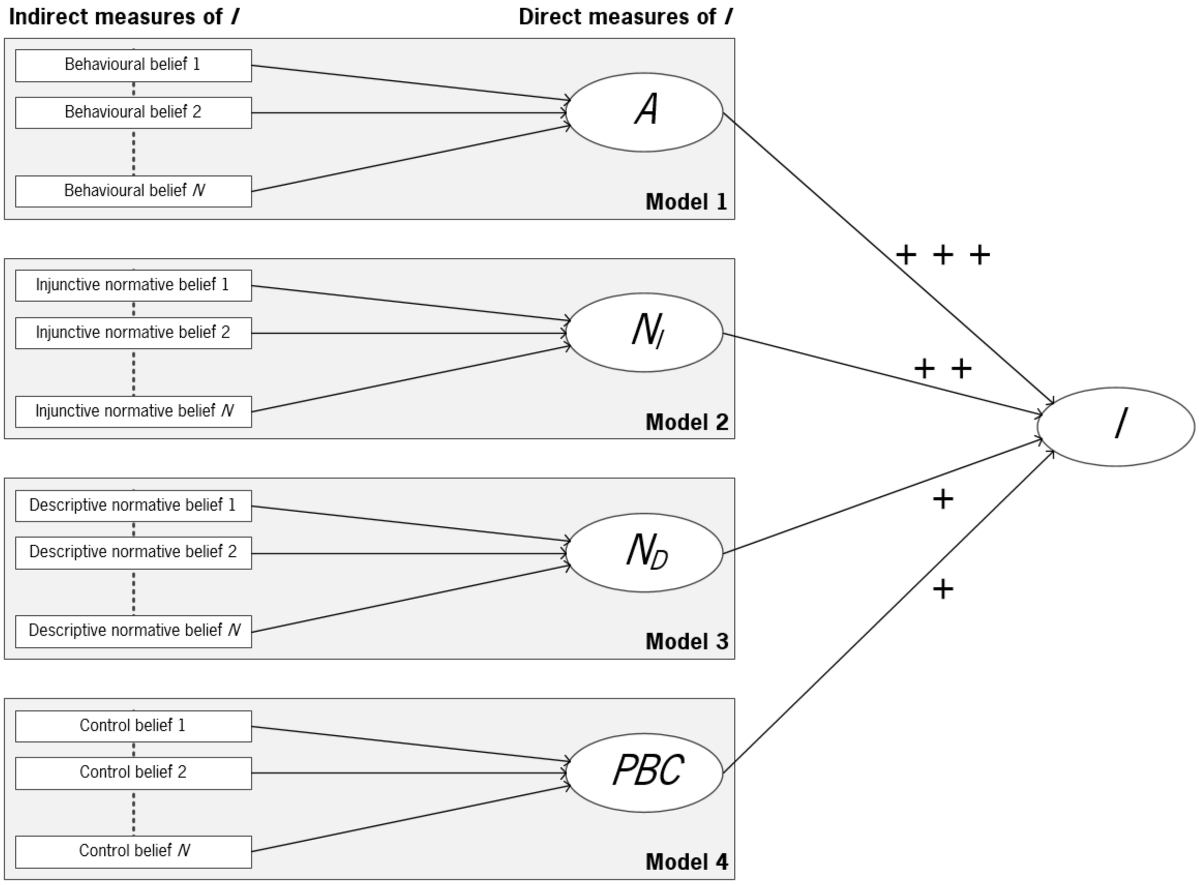

Figure 4-1: Framework based on the reasoned action approach (RAA). The number of plusses indicate the relative importance of each construct on intention.

The abovementioned constructs can be measured either directly or indirectly. Sok et al. (2016b) estimated them with direct measures only. This was done for two reasons (Montaño and Kasprzyk, 2008): (1) direct measures are usually more strongly associated with intentions than indirect measures, and (2) the associations between direct measures and intentions indicate the relative importance of the constructs in predicting a given behaviour.

Results revealed that the farmers' intention to participate in a reactive vaccination scheme against BT is mainly attitude-driven, however, normative considerations (social pressures) also influenced intention formation, with injunctive norms being more important than descriptive norms (Sok et al., 2016b). Given this result, the relative importance of the constructs on I is indicated in Figure 1 by the number of plusses, with more plusses indicating a greater importance. This implies that attitudinal and injunctive normative beliefs outweigh the descriptive normative and control beliefs (indirect measures).

The next section elaborates on how beliefs are identified and elicited, and subsequently analyzed to find the drivers behind the intention to participate in a voluntary hypothetical reactive vaccination scheme against BT.

4.3 Material and methods

4.3.1 Identification, elicitation and models for analyzing beliefs

The first step in applying the RAA is the identification and elicitation of farmers' beliefs. For this step, semi-qualitative interviews were held in May/June 2013 with 7 dairy farmers and 1 veterinarian from different parts within the Netherlands. To obtain a set of underlying beliefs for each construct, A, NI, ND and PBC, each respondent was asked a number of questions. In order to obtain the attitudinal beliefs underlying A, interviewees were asked to list the (dis)advantages of performing the behaviour under study. In case of injunctive normative beliefs underlying NI, interviewees were asked to list the individuals or groups who would (dis)approve of their performing the behaviour under study. To obtain descriptive normative beliefs underlying ND, interviewees were asked to list the individuals or groups for which it was expected that they will perform the behaviour under study. In case of control beliefs underlying PBC, interviewees were asked to list factors or circumstances that would make it more easy (difficult) and/or persuade (dissuade) him or her to perform the behaviour under study. All responses from the 7 dairy farmers (and 1 veterinarian) were listed and subsequently analyzed on the main recurring beliefs.

Since there are four main psychological constructs – A, NI, ND and PBC – that can determine I, four different models were central (see Figure 1) for analyzing the main recurring beliefs identified. They can be represented by the following equations:

$$A = f(b_{ij}e_{ij}), \tag{1}$$

where A is the farmer's positive or negative evaluation of performing that behaviour, b_{ij} the strength of the attitudinal belief about attribute i ($i = 1, 2, \dots, 5$) in statement j ($j = 1, 2$) and e_i the evaluation of attribute i ($i = 1, 2, \dots, 5$) in statement j ($j = 1, 2$);

$$\mathrm{N_I = f(in_k m_k)}, \tag{2}$$

where N_I is farmers' perception of what referents think they he or she should do, in_j the injunctive normative belief about referent k ($k = 1, 2, \dots, 12$) and m_k the motivation to comply with referent k ($k = 1, 2, \dots, 12$);

$$N_D = f(dn_l i_l), \tag{3}$$

where N_D is the perceived behaviour of other farmers, dn_l the descriptive normative belief about referent l ($l = 1, 2, \dots, 4$) and i_l the identification with referent l ($l = 1, 2, \dots, 4$);

$$PBC = f(c_{mn} p_{mn}), \tag{4}$$

where PBC is the perceived personal capability to perform that behaviour, c_{mn} the belief of the presence of control factor m ($m = 1, 2, \dots, 5$) in statement n ($n = 1, 2$) and p_{mn} the power of control factor m ($m = 1, 2, \dots, 5$) in statement n ($n = 1, 2$).

In each equation, a multiplicative composite, such as $b_{11}e_{11}$ or $in_2 m_2$, is the product of a belief with an outcome evaluation, with a possible score ranging from -10 to 10. Originally, this idea of measurement stems from the expectancy-value model, initially applied to attitude measurement (Feather, 1959; Fishbein, 1963).

4.3.2 Questionnaire and sample

Table 1 presents the attitudinal belief statements that were incorporated in the questionnaire. Each belief statement was preceded with the phrase: "Were bluetongue to occur in my environment this year and I was to vaccinate", and measured on a 5-point unipolar[2] Likert type scale with endpoints from 'Not likely' to 'Very likely'. Each outcome evaluation (evaluation of attribute) statement was preceded with the phrase: "Will the following motives be important if you consider preventive vaccination of your herd if bluetongue were to occur in your environment this year?", and measured on a 5-point bipolar Likert type scale with endpoints from 'Important' to 'Unimportant'.

For each injunctive referent considered in the questionnaire (Table 2), the normative belief statement was formulated as: "What is the opinion of <referent k> about preventive vaccination of your herd if bluetongue were to occur in your environment this year?", and was measured on a 5-point bipolar Likert type scale with endpoints from 'Strongly against' to 'Highly in favour'.

[2] Whether the measurement scale should be unipolar or bipolar was determined by looking at the nature of the concept measured (e.g. Francis et al., 2004). For example, the attitudinal belief about an attribute can be characterized as a probability, which is a unidirectional concept, and thus a unipolar measurement scale is more appropriate, while for an attribute evaluation a bipolar measurement scale is most realistic.

Each outcome evaluation (motivation to comply to referent k) statement was formulated as: “Is the opinion of <referent k> important to you when considering preventive vaccination of your herd if bluetongue were to occur in your environment this year?”, and was measured on a 5-point unipolar Likert type scale with endpoints from ‘Unimportant’ to ‘Very important’.

For each descriptive referent considered in the questionnaire (Table 3), the normative belief statement was formulated as: ‘Is <referent l> going to preventively vaccinate his or her herd if bluetongue were to occur this year in the environment?’, and was measured on a 5-point bipolar Likert type scale with endpoints from ‘Definitely not’ to ‘Definitely’. Each outcome evaluation (identification with referent l) statement was formulated as: “Is what <referent l> is going to do if bluetongue were to occur in the environment this year important for your consideration to vaccine your herd preventively?”, and was measured on a 5-point unipolar Likert type scale with endpoints from ‘Unimportant’ to ‘Very important’. In both the injunctive and descriptive normative section a ‘Not applicable’ (*NA*) option was included.

Table 4 presents the description of the control belief statements that were incorporated in the questionnaire. Each belief statement was preceded with the phrase: “If a voluntary vaccination scheme was to be announced when bluetongue were to occur in my environment this year”, and measured on a 5-point unipolar Likert type scale with endpoints from ‘Unlikely’ to ‘Very likely’. Each outcome evaluation (power of control factor) statement was preceded with the phrase: “Will the following issues make it easier (persuade) or more difficult (dissuade) for you to vaccinate your herd preventively if bluetongue were to occur in your environment this year?”, and measured on a 5-point bipolar Likert type scale with endpoints from ‘More difficult / dissuade’ to ‘Easier / persuade’.

A random sample of 1,500 Dutch dairy farms was drawn from the National Cattle Identification and Registration Database. Only farms with a herd size of at least 40 dairy cows were selected, as these are more likely to be professional dairy farmers rather than hobby farmers. Hobby farmers were excluded because their vaccination decisions, in the face of a threat of a bluetongue infection, involves different arguments that are more likely driven by idealistic motives (Elbers et al., 2010).

The questionnaire was pre-tested with two dairy farmers to check for flaws or problems with interpretation of questions. The final, revised questionnaire, along with a pre-paid return envelope and an accompanying letter, was sent out in the second week of January 2014. Farmers were offered two possibilities to fill in the questionnaire, i.e. using the paper copy, or an on-line survey. Each respondent had a 10 per cent chance of winning a gift coupon of € 25. After 4 weeks, a reminder was sent to all farmers in the sample. The final response, the 415^{th}, was returned around mid-March, resulting in a response rate of almost 28 per cent

4.3.3 Statistical model

In a related empirical study using the RAA, structural equation modelling (SEM) is applied (Sok et al., 2016b). I, A, N_I, N_D and PBC are represented by a set of correlated effect indicators and analyzed as latent variables, to investigate the presence of causal relations as specified in the RAA. In this study, beliefs (multiplicative composites) will be the causal indicators that have an impact on the associated determinants of intention. To be able to include causal indicators, some form of formative instead of reflective measurement is needed[3]. A suitable approach that allows for both forms of measurement is the multiple indicators and multiple causes (MIMIC) model (Jöreskog and Goldberger, 1975), which is the SEM equivalent for multiple regression.

Using MIMIC models, an index of multiplicative composites is analyzed as a set of causal indicators explaining a latent variable (Diamantopoulos and Winklhofer, 2001). The MIMIC model can be formally described as follows:

$$y = \varDelta\eta + \epsilon \qquad (5)$$

$$\eta = \varGamma x + \zeta \qquad (6)$$

where in equation 5 y is a vector of effect indicators of latent variable η (e.g. A or NI), Δ a matrix of factor loadings and ϵ a vector of measurement error[4].

In equation 6, x (e.g. be_1 or inm_1) is a vector of causal indicators on η, Γ a matrix of regression coefficients γ's of e.g. be_1 or inm_1 on its associated η, and ζ a vector of error terms. It is furthermore assumed that the ε's are uncorrelated with the ζ's.

[3] For a background discussion on the distinction between effect and causal indicators, between formative and reflective measurement models and selection criteria, e.g. see Diamantopoulos and Winklhofer (2001); Jarvis et al. (2003); Kline (2011).

[4] Justification how this part is established and how the latent variables η are represented, can be found in Sok et al. (2016).

4.3.4 Data screening and preparation

An initial screening of the data on missing values was made: 25 observations (6 per cent) were dropped because they had missing data on all indicators of all direct measures for I, A, N_I, N_D and PBC. Next, in each model for the indirect measures, observations were dropped when they had missing data on all belief indicators and/or all outcome evaluations. This led to dropping 10 observations in the $b_{ij}e_{ij}$ section, 23 in the $in_k m_k$ section, 21 in the $dn_l i_l$ section, and 5 in the $c_{mn}p_{mn}$ section.

For each attribute i, multiplicative composites were averaged if (1) both had a significant correlation with A and (2) showed a high internal consistency reliability as measured by Cronbach's alpha (α_C).

The number of *NA* ticks in the injunctive and descriptive normative section for a particular referent is understood as an indication of the importance of that referent in the sample for the behaviour under study. The *NA* option was not included in the continuous underlying distribution, as is often done by recoding *NA* ticks to the middle tick of the Likert type scale. Instead, the number of *NA* ticks were treated as a categorical and not continuous type of missing data and in this way functioned as a selection criterion to determine which referents to include in subsequent analyses. Only those referents were included in the analysis who had less than 25 per cent *NA* ticks.

Since formative measurement is based on multiple regression, multicollinearity can be an issue (Diamantopoulos and Winklhofer, 2001). Kline (2011) indicates that a variance inflation factor (VIF) of >10 is indicating that variables may be redundant. The highest VIF was found in the linear regression of *'Effectiveness'* on all other control factors, which was 3.14. It is concluded that there is mild collinearity among the control factors but not up to a level that is considered problematic. For the remaining determinants of intention there was only negligible to weak collinearity.

4.3.5 Model assessment

Assuming that the (composite) scales reflect continuous underlying distributions, maximum likelihood (ML) estimation is used, which is the default SEM estimation method. Overall model fit of the MIMIC models is assessed first with the default χ^2 test statistic. The null hypothesis tested here is that the sample covariance matrices equal the hypothesized covariance matrices. This test only shows whether the model is consistent with the data. Three commonly used approximate fit indexes were used to test whether the model was also correctly specified: the Steiger-Lind root mean square error of approximation (RMSEA) which is a parsimony-corrected index, the Bentler Comparative Fit

Index (CFI) which is an incremental fit index, and the Standardized Root Mean Square Residual (SRMR) which is an absolute fit index, a statistic related to the covariance residuals (Hair et al., 2010; Kline, 2011). Overall model fit was further examined by inspecting (1) the matrix of standardized covariance residuals, which shows any difficulties the model has with fitting covariances, and (2) the modification indexes, which give suggestions for model improvement by freeing any single relationship that is not currently estimated.

The MIMIC model with referents l causing ND failed some identification rules, specifically the t rule and the 2+ emitted path rule (Bollen and Davis, 2009). Therefore, a global reflectively-measured latent variable was included to overcome the identification problems and allowing overall model fit assessment (Diamantopoulos et al., 2008). The intention construct, represented by three indicators, was added to this model.

Once the overall model fit was assured, the impact of causal indicators on the associated determinants of intention was studied by looking at the direction and magnitude of the regression coefficients (γ-parameters). Following the approach of Diamantopoulos and Winklhofer (2001) in estimating the MIMIC model, non-significant indicators that exceeded the 10% critical significance level were removed one at a time in an iterative process, starting with the indicators that had the lowest t-value.

4.4 Results

4.4.1 Measured beliefs

The causal indicators for each determinant of intention – A, NI, ND and PBC – are presented in Tables 1 – 4 respectively. An indicator is a multiplicative composite consisting of a belief statement with its associated outcome evaluation statement. Descriptive statistics of each indicator (ind.) are given in the tables, namely the number of observations (n), correlation ($corr$) with the associated determinant of intention and the mean (M) and standard error of the mean (SE_M).

In the model for A (Table 1), attributes are represented by the average of two associated indicators. Some attributes were only represented by one indicator, because of low internal consistency (measured with $\propto_C$) and weakly correlated statements (see section 'Data screening and preparation'). This happened often in case the statements were negatively formulated. A similar approach was used for control factors in the model for PBC (Table 4).

In the models for NI and ND (Table 2 and 3 respectively), two columns were added with the number of observations excluding *NA* scores (n excl. *NA*) and the ratio between the columns n and n excl. *NA*, expressed in a percentage (% excl. *NA*). This column was generated to decide which referents to include (see section 'Data screening and preparation').

All correlations between the attributes, referents and control factors and their belonging constructs had the *a priori* expected sign, e.g. the attribute 'Time and effort' is negatively correlated with A and the control factor 'Effectiveness' is positively correlated with PBC.

Table 4-1: Description and some descriptive statistics of the attitudinal beliefs identified.

Attributes	Ind.	Attitudinal belief statement *Were bluetongue to occur in my environment this year and I was to vaccinate will …*	n	*corr* [b]	α_C [d]	*M* (*SE*$_M$)
1.Production distortions	be_{11}	it have to cope with negative side effects and/or stress.[a]	377	-0.17	0.33	1.15 (4.41)
	be_{12}	vaccination negatively influence the physical condition and performance of my herd.[a]	377	0.08[c]		2.12 (4.19)
2. Coll. dis. eradication	be_{21}	it contribute to the eradication of bluetongue in the Netherlands (at that moment).	378	0.39	0.76	2.20 (3.96)
	be_{22}	further spreading of bluetongue be inhibited (at that moment).	378	0.50		3.25 (3.93)
3. Time and effort	be_{31}	the amount of work involved with vaccination be little.	379	-0.23	0.77	-2.06 (4.56)
	be_{32}	the preparation and performance of the vaccination take a lot of time.[a]	379	-0.21		-1.96 (4.26)
4. Risk insurance	be_{41}	the risk of getting economic damage from bluetongue at my farm be reduced.	378	0.59	0.32	4.69 (3.97)
	be_{42}	the costs of vaccination be in the right proportion to the economic risk from bluetongue	378	0.01[c]		1.87 (3.83)
5. Job satisfaction	be_{51}	be insured that I can continue working with a healthy herd.	379	0.55	0.66	4.52 (3.24)
	be_{52}	possible harrowing disease cases in my herd be prevented.	379	0.42		3.54 (3.73)

[a] Those statements were negatively formulated and thus reversed.
[b] Each multiplicative composite was pair-wisely correlated with the average of the indicators representing the latent variable A.
[c] No significant correlation with A.
[d] With Cronbach's alpha ($\propto_C$) the internal consistency reliability was measured for each pair of multiplicative composites representing an attribute

4.4.1.1 Behavioural outcomes for attitude

Attitudinal beliefs identified from the semi-qualitative interview sessions were grouped into five attributes. These were a mix of instrumental (economic) and experiential (affective) attributes. The attribute which obtained the highest mean rank score was 'Risk insurance', to be insured against economic damage of BT. Other attributes with mainly instrumental economic orientations in order of mean rank score were 'Collective disease eradication', the individual contribution to support controlling the spread of BT; and 'Time and effort', the time and effort needed to prepare and perform the vaccination.

The orientation between instrumental and experiential was less clear-cut for ‘Production distortions’. On the one hand, this attribute could be economically-oriented in terms of a loss of technical performance and thereby efficiency losses. On the other hand it could be experientially-oriented, as something farmers do not want to be confronted with having cows in bad health after vaccination against BT. The latter related to the experientially-oriented attribute ‘Job satisfaction’, which was mean ranked second highest. Most of the farmers interviewed indicated they did not want to be emotionally confronted with cows seriously suffering from the consequences of BT.

4.4.1.2 Normative referents for perceived norms

For the perceived norm construct, a distinction was made between injunctive norms (N_I) and descriptive norms (N_D). A total of 13 salient referents were identified from the interview sessions. Three referents were both classified as injunctive as well as descriptive norms. For example, a farmer (the respondent) has a perception of what fellow dairy farmers think he or she should do but at the same time takes into account the perceived behaviour of these fellow dairy farmers.

Regarding respondents’ injunctive referents, six out of the twelve selected referents had less than 25 per cent *NA* ticks (underlined in Table 2). The ‘Veterinarian’ was the most important referent with 5 per cent *NA* ticks and the highest mean rank score. In order of mean rank score, the other referents selected were ‘Milk buyer’, ‘Fellow dairy farmers’, ‘Feed advisor’, ’Leaders / representatives’ and ‘Family and/or friends’.

Regarding respondents’ descriptive referents, three out of the four selected referents had less than 25 per cent *NA* ticks (underlined in Table 3). ‘Colleague dairy farmers’, was the most important referent with about 9 per cent *NA* ticks. The other referents selected were ‘Leaders / representatives’ and ‘Dairy farmers in the media’. All three selected referents had fairly low comparable mean rank scores.

Table 4-2: Description and some descriptive statistics of the injunctive normative referents identified

Referent	Ind.	n	n excl. *NA*	% *NA* [a]	*corr* [b]	*M* (*SE_M*)
1. Veterinarian	inm_1	363	345	5.0	0.38	5.87 (3.45)
2. Study club members	inm_2	361	187	48.2	0.28	1.19 (2.64)
3. Exporter breeding cattle	inm_3	364	186	48.9	0.16	3.08 (4.34)
4. Animal welfare organization / society	inm_4	364	255	29.9	0.36	2.51 (3.07)
5. Contact bank / accountant	inm_5	365	244	33.2	0.41	1.52 (3.05)
6. Colleague dairy farmers	inm_6	361	317	12.2	0.33	2.37 (3.15)
7. Milk buyer	inm_7	364	322	11.5	0.30	4.14 (3.99)
8. Government representative	inm_8	363	239	34.2	0.21	1.39 (3.02)
9. Feed advisor	inm_9	364	305	16.2	0.34	2.69 (3.15)
10. Family and/or friends	inm_{10}	365	282	22.7	0.39	1.53 (3.04)
11. Leaders / representatives	inm_{11}	363	274	24.5	0.37	2.57 (3.03)
12. Fellow believers	inm_{12}	367	170	53.7	0.28	0.56 (2.52)

[a] Referents were included in the statistical analysis when less than 25% was a *NA* score
[b] Each multiplicative composite was correlated with the average of the indicators representing the latent variable N_I.

Table 4-3: Description and some descriptive statistics of the descriptive normative referents identified

Referent	Ind.	n	n excl. *NA*	% *NA* [a]	*corr* [b]	*M* (*SE_M*)
1. Leaders / representatives	dni_1	368	297	19.3	0.27	2.00 (2.68)
2. Study club members	dni_2	368	214	41.8	0.33	1.09 (2.28)
3. Colleague dairy farmers	dni_3	369	335	9.2	0.35	1.56 (2.75)
4. Dairy farmers in the media	dni_4	368	323	12.2	0.31	1.71 (2.52)

[a] Referents were included in the statistical analysis when less than 25% was a *NA* score
[b] Each multiplicative composite was correlated with the average of the indicators representing the latent variable N_I.

4.4.1.3 Control factors for perceived behavioural control

The control beliefs identified from the semi-qualitative interview sessions were grouped into five control factors encompassing four external and one internal. The external control factor which obtained the highest mean rank score was 'Communication', i.e. the provision of reliable information that can be trusted. Other external control factors in order of mean rank score were 'Effectiveness', mainly the effectiveness of the vaccine (strategy); 'Compensation', not only to lower costs of vaccination but also as a signal of seriousness; and 'External organization', particularly the red tape. The internal control factor was 'Internal organization', the easiness with which vaccination could be performed at the farm, e.g. to lock up the cows by the feeding fence.

Table 4-4: Description and some descriptive statistics of the control beliefs identified.

Control factors	Ind.	Control belief statement *If a voluntary vaccination program was to be announced when bluetongue were to occur in my environment this year will ...*	n	*corr* [b]	α_C [d]	$M(SE_M)$
1. Comm.	cp_{11}	I receive sufficient inform. about the purposes and necessity of preventive vaccination.	383	0.32	0.82	3.60 (3.87)
	cp_{12}	they give me a solid justification why preventive vaccination is required.	382	0.37		4.03 (3.58)
2. Internal organization	cp_{21}	vaccination be easy to perform on my farm.	382	0.27	0.02	3.81 (3.91)
	cp_{22}	a vaccination round be difficult to organize at my farm.[a]	383	-0.09[c]		1.14 (4.70)
3. Compens.	cp_{31}	I have sufficient resources available to pay such an unforeseen expense.	382	0.24	0.78	3.05 (3.94)
	cp_{32}	I not be able to cover the costs of preventive vaccination.[a]	383	0.26		2.80 (4.28)
4. Effective.	cp_{41}	it be clear to me how the available vaccine functions.	383	0.24	0.73	3.10 (3.08)
	cp_{42}	the available vaccine do what it needs to do, and nothing else.	380	0.38		3.72 (3.22)
5. External organization	cp_{51}	(government) organizations employ an efficient policy.	383	0.28	0.04	2.28 (3.10)
	cp_{52}	the registering to join in the programme be laborious.[a]	383	-0.06[c]		1.70 (4.16)

[a] Those statements were negatively formulated and thus reversed.
[b] Each multiplicative composite was pair-wisely correlated with the average of the indicators representing the latent variable PBC.
[c] No significant correlation with PBC.
[d] With Cronbach's alpha ($\propto_C$) the internal consistency reliability was measured for each pair of multiplicative composites representing an attribute

4.4.2 Mimic models

Figure 2 illustrates the MIMIC model using the results for the attributes be_i causing A. Table 5 presents the overall model fit indexes and the relative importance of the causal effects on the associated determinant of intention.

Based on the guidelines for establishing (un)acceptable fit provided by Hair et al. (2010), the model with attributes be_i causing A had an excellent fit. The attributes together explained 54 per cent of the variance in A. The model with referents k causing NI had a good fit; here the referents explained 36 per cent of the variance in NI. Also, the model with referents l causing ND had a good fit as the referents selected explained 27 per cent of the variance in ND. The overall model fit indices evaluated a model in which a global reflectively-measured latent variable was included for identification purposes (see section 'Model assessment').

The model with control factors cp_m causing PBC showed a good fit, even though the RMSEA was only 0.111. However, the RMSEA falsely indicates a poor fit since the df was only 1 (Kenny et al., 2014). Poor fit can be diagnosed by specifying additional models that include deleted parameters. With the non-significant control factors included to increase the df, the model fit was as follows: χ^2 = 7.13 with df = 4, p < .129; RMSEA = .046; SRMR = .007; CFI = 0.991. In both model specifications, the control factors explained 18 per cent of the variance in PBC.

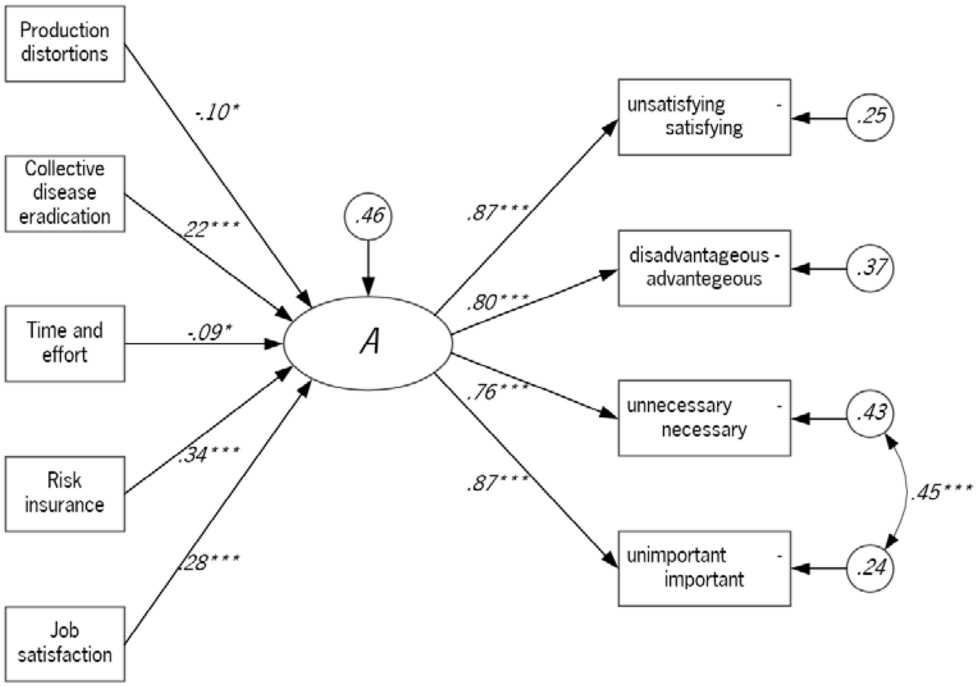

Figure 4-2: An illustration of the MIMIC model with attributes be_i causing A.

Results reported no influential standardized covariance residuals. A few weak influential modification indices were reported suggesting omitted paths between a cause and one particular reflective indicator. For example, in the model with referents k causing NI, there were two suggested omitted paths from the referents 'Veterinarian' and 'Leaders / representatives' to a particular reflective indicator of NI that was formulated as: […] people in the industry whose opinions I value […]. Therefore, the suggested omitted paths can be theoretically explained as both referents are people from the industry. However, there is no further justification for the inclusion of these paths. The causal effect is estimated via paths from both referents to the latent construct NI.

Focussing on the relative importance of the causal effects on the associated determinant of intention, all parameters that were statistically significant had the expected sign (see Table 5). Regarding the model with attributes be_i causing A, 'Risk insurance' obtained the highest γ-parameter, followed by 'Job satisfaction' and 'Collective disease eradication'. Although significant at the 5 per cent critical level, the negative coefficients of 'Production distortions' and 'Time and effort' were low. Thus, the most influential attitudinal belief underlying the evaluation to perform preventive vaccination against BT was to be insured against the economic damage of the disease. Yet another influential underlying attitudinal belief was the 'psychological insurance' against the chance of facing harrowing disease cases and to be emotionally confronted with cows seriously suffering from the consequences of BT. The third in the order of influential beliefs was that with preventive vaccination a contribution is made to the eradication of the disease.

Regarding the model with referents k causing N_I, 'Family and/or friends' obtained the highest γ-parameter, immediately followed by 'Veterinarian'. The third in order of influential injunctive referents was 'Colleague dairy farmers'. Thus, the most influential referents underlying the respondents' perceived injunctive norms are relatives and the veterinarian. It should be noted here that although almost equal in relative importance, the 'Veterinarian' was the most important and highest mean ranked referent compared to the other injunctive referents[5]. Regarding the model with referents l causing N_D, 'Colleague dairy farmers' obtained the highest γ-parameter, followed by 'Leaders / representatives' and 'Dairy farmers in the media'. Thus, the most influential referent underlying the respondents' perceived descriptive norms are 'Fellow dairy farmers'.

Table 4-5: Estimates of the various MIMIC models.

Cause	Causal effect of γ on…				p
	η_A	η_{NI}	η_{ND}	η_{PBC}	
γ_{be1}	-.105				.012
γ_{be2}	.218				.000
γ_{be3}	-.093				.027
γ_{be4}	.341				.000
γ_{be5}	.277				.000
γ_{inm1}		.209			.001
γ_{inm6}		.174			.005
γ_{inm7}		.113			.075
γ_{inm10}		.222			.000
γ_{inm11}		.158			.014
γ_{dni1}			.176		.010
γ_{dni3}			.308		.000
γ_{dni4}			.179		.012
γ_{cp1}				.239	.004
γ_{cp4}				.210	.010
N	362	244	287	373	
χ^2	20.52	17.37	23.57	5.60	
df	16	10	11	1	
$p <$	.198	.067	.015	.018	
RMSEA	.028	.055	.063	.111	
SRMR	.016	.025	.049	.008	
CFI	.996	.982	.987	.988	

[5] Different model specifications were run to check the robustness of the coefficients. A model specification with inm_1 and inm_{10} in the index gave the following coefficients: γ_{inm1} = .320 and γ_{inm10} = .304 with n = 274. A model specification with only inm_1 gave the following coefficient: γ_{inm1} = .412 with n = 343. A model specification with only inm_{10} gave the following coefficient: γ_{inm10} = .434 with n = 280. From the different model specifications it can be concluded that the two referents stay equally important.

Regarding the model with control factors cp_m causing PBC, 'Communication' obtained the highest γ-parameter, immediately followed by 'Effectiveness', both external control factors. Thus, the most influential control belief underlying the respondents' perceived own capability to perform the behaviour had to do with the communication of the responsible institutions to the farmers related to the justification and the necessity of preventive vaccination. Yet another influential underlying control belief related to the effectiveness of the vaccine (strategy).

4.5 Discussion

According to Fishbein and Ajzen (1975; 2010), beliefs are subjective probabilities, and they can be established in three different ways: via (1) descriptive belief formation, which results from direct observation; (2) informational belief formation, which results from accepting information from some outside source; or (3) inferential belief formation, which results from a process of inference from some other belief.

Attitudinal beliefs about attributes can be classified into instrumental (economic) and experiential (affective) aspects of attitude (Fishbein and Ajzen, 2010). Thus, for the influential attitudinal beliefs found in this study, 'Risk insurance' and 'Collective disease eradication' are instrumental and 'Job satisfaction' is experiential in nature. Especially for the instrumental attributes, a more favourable attitude can be stimulated through information belief formation, a careful use of the communication intervention as a policy instrument to demonstrate the exposure to the potential risks of no vaccination at the farm but also country-wide. The significance of communication is confirmed as it was one of the influential external control factors ('Communication'). As this information needs to be 'accepted from an outside source', the selected risk communication channels through which information is sent matter. As Garforth et al. (2004: p. 28) observed: "local and personal contacts generally have more influence on farmers' intentions than more distant and impersonal sources".

Trust and credibility determine the success in changing attitudinal beliefs in risk communication. Information is more likely accepted if there is a credible communicator, a high level of 'similarity' between the audience and communicator and both the message and communicator must be perceived as trustworthy (Petty and Cacioppo, 1996). Trust and credibility are also crucial in the case of BT vaccination, particularly if farmers might have lost confidence in a publicly organized vaccination programme due to a contaminated vaccine offered in the past (Barkema et al., 2001; Elbers et al., 2010).

The latter might provide an explanation of why the external control factor ‘Effectiveness’ is influential. Hence, all of the above justifies why in 2008 not only the Ministry itself but also farmer organizations recommended vaccination and farmer meetings were used to communicate.

Another policy instrument used in 2008 was subsidization of the costs of vaccination. From economic theory, it can be argued that when the probability of infection is high and expected economic consequences are large, vaccination provides a similar protection as insurance against the risk of infection. Farmers who perceive a high probability of infection without vaccination and expect large economic consequences of infection without vaccination will have a strong incentive to vaccinate. This was most likely the case in 2006 and 2007 for farmers in the southern and central part of the Netherlands, who experienced the negative effects of infection on their livestock (Schaik et al., 2008). In these circumstances, subsidization of vaccination might only have had a small effect on the motivation of a farmer to participate in a vaccination campaign (Sok et al., 2014). On the other hand, farmers in the northern part of the Netherlands might have perceived the risk of infection to be rather low in 2008, although in this area the largest proportion of susceptible animals was present. The 2008 vaccination plan indicated that “special attention needs to be given to areas for which it is known that the bluetongue seroprevalence is relatively low” (Ministry of Economic Affairs, 2008: p. 6). Hence, subsidization was used to provide an economic incentive to farmers in low prevalence areas to vaccinate. Moreover, providing subsidies (as opposed to fines) might also have served as an indicator of the seriousness with which the government was taking her responsibility, and therefore could well have been a complement to the communicative intervention that aims at motivating farmers intrinsically.

A key assumption in RAA is that beliefs do not have to be rational, nor have to be instinctive or stable over time. They are formed in daily encounters in the real world (Fishbein and Ajzen, 2010). The only assumption made in the RAA is that one’s behaviour follows reasonably from beliefs. Therefore, it is very likely that the direct or indirect experiences with the consequences of the BT epidemic of 2006 – 2009 are captured within attitudinal beliefs through descriptive and/or inferential belief formation. In other words, farmers might have been basing their responses on their direct and indirect experiences with BT when filling in the questionnaire. Diverging BT experiences from the past could have led to a different set of influential attitudinal beliefs for different groups. Farmers in the southern part might have been more concerned with ‘Production distortions’ than farmers in the northern part of the Netherlands, because the BT prevalence was the highest in the southern part, where the outbreak started, and decreased towards the north (Elbers et al., 2008c; Schaik et al., 2008). Furthermore, Elbers et al. (2010) reported that the probability of BT vaccine uptake in 2009 increased if farmers had experienced BT in the preceding years. This is in line with the assertion of RAA that beliefs are not necessarily rational. From a rational point of view, vaccination is less profitable if the herd has become immune through natural infection. Thus, some farmers might base, for a major part, their vaccination decisions on direct and indirect experiences with animal diseases no matter whether that decision is rational or not. Personal characteristics, such as the individuals' goals, values or conscientiousness can address these decisions (Willock et al., 1999; Austin et al., 2001). It can provide explanations why attitudinal beliefs are not always instrumental but can also be experientially-oriented, like the case of 'Job satisfaction' is showing (Gasson, 1973). Such contextual and personal factors can be used to address heterogeneity in beliefs among farmers.

The most influential normative beliefs found in this study were 'Family and friends' and 'Veterinarian', followed by 'Colleague dairy farmers'. The way these beliefs are formed is not exclusive, in fact, all three different ways of belief formation may be true. The multiplicative composite of 'Family and friends' (see Appendix) consisted of a low belief score (0.44) and a moderate outcome evaluation score (2.80). Thus, the influence of relatives is not so much determined by a strong opinion relatives hold in favour of the behaviour under study, rather the normative influence itself is more important. This likely relates to the fact that Dutch dairy farms usually are family businesses; factors such as the case of multiple decision makers, the stage in the family cycle and the dependence of family income from farm operations are taken into account in the decision-making process (Gasson et al., 1988; Burton, 2006).

The multiplicative composite of 'Veterinarian' (see Appendix) consisted of a highly positive belief score (1.41) and a high outcome evaluation score (4.01). Thus, most farmers perceive the veterinarian's opinion to be in favour of vaccination while this normative belief is also important. This finding is in line with previous research showing that the veterinarian is being perceived as a highly trusted and influential referent in herd health management (e.g. Ellis-Iversen et al., 2010; Kristensen and Jakobsen, 2011; Lam et al., 2011; Derks et al., 2013; Fisher, 2013). This suggests that for future BT alike vaccination strategies, the social interactions between veterinarians and farmers might be an appropriate communication channel to use.

'Fellow dairy farmers' was the third in order of important injunctive normative beliefs, while being the most important descriptive normative belief. In both cases, the belief score was barely positive (0.60 and 0.42 respectively) and the outcome evaluation score moderate (3.30 and 2.96 respectively) (see Appendix). The low scores might indicate that farmers had difficulties with forming a belief about (estimating a probability) and evaluating the outcome of normative influences from fellow dairy farmers for a hypothetical reactive vaccination scheme. Nevertheless, the fact that fellow dairy farmers are an influential referent in both type of norms suggests that social interactions among farmers about vaccination decisions exist. In case these social interactions are confidence-based, the belief can be formed through either descriptive (direct observation) or informational belief formation (accepting information). If there is more distance, the belief can be formed through inferential belief formation. Farmers may base their inferences on prior descriptive beliefs, such as beliefs concerning a colleague dairy farmer's personality or his or her farming style.

The preceding illustrates the complexity of understanding collective voluntary vaccination. Eradication programmes have characteristics of collectively produced goods (Oude Lansink, 2011), i.e. the success of eradication programmes depends on the success of collective action, while for an economic rational decision maker, the positive externality of a reduced likelihood of infection for colleague farmers is not an incentive to vaccinate (Rat-Aspert and Fourichon, 2010; Sok et al., 2014). This view, where each individual farmer is expected to behave autonomously and self-interested, might be an 'undersocialized' view (Granovetter, 1985); collective voluntary behaviour is also likely driven by social interactions within a community or network of farmers. In the latter, behavioural 'rules' that influence the collective outcome are e.g. norms of reciprocity, reputation, group identity, solidarity and trust, which are all elements of (informal) social capital (e.g. Mathijs, 2003; Burton et al., 2008; Sutherland and Burton, 2011).

Peer group pressure is also indicated to be a policy instrument that can externally motivate voluntary behaviour (Van Woerkum, 1990). As this research has shown that social interaction among farmers exist, future research is needed to study more deeply the underlying mechanisms of social interactions that influence farmers' decision-making with regard to private and public interests of controlling future BT alike disease epidemics.

4.6 Conclusions

In the 2008 vaccination strategy against bluetongue, the policy instruments used largely fitted in with the influential beliefs of dairy farmers that drove the intention to participate in a voluntary vaccination scheme.

The analysis of the beliefs shows that for a communication intervention, the communication channels used need to be credible and trusted by farmers. As farmers seem to already have intrinsic motivations to vaccinate, subsidization can complement a communication intervention to stress the seriousness with which the government takes her responsibility.

Given that social interactions among farmers about vaccination decisions exist, social interaction mechanisms, such as peer group pressure, might take the role of a 'catalyst' among the mix of policy instruments used in voluntary vaccination strategies.

Appendix

Appendix table A4.1: Rank scores and some descriptive statistics of the attitudinal beliefs (b_{ij}) and outcome evaluations (e_{ij}).

	Not likely > > Very likely						
Ind.	1	2	3	4	5	Obs.	Mean (SE_M)
b_{11}	26	83	111	95	63	378	3.22 (1.17)
b_{12}	20	60	125	108	66	379	3.37 (1.10)
b_{21}	40	67	82	139	51	379	3.25 (1.20)
b_{22}	25	25	80	174	75	379	3.66 (1.07)
b_{31}	17	55	100	137	70	379	3.50 (1.09)
b_{32}	33	60	111	122	53	379	3.27 (1.15)
b_{41}	14	26	63	169	107	379	3.87 (1.02)
b_{42}	40	64	152	93	30	379	3.02 (1.07)
b_{51}	41	50	109	138	41	379	3.23 (1.15)
b_{52}	31	37	110	145	57	380	3.42 (1.11)
	Of no importance < > Of importance						
Ind.	-2	-1	0	1	2	Obs.	Mean (SE_M)
e_{11}	34	53	70	139	83	379	.49 (1.23)
e_{12}	18	38	76	154	92	378	.70 (1.09)
e_{21}	29	43	85	157	65	379	.49 (1.13)
e_{22}	18	28	79	167	87	379	.73 (1.04)
e_{31}	89	101	96	65	29	380	-.41 (1.23)
e_{32}	88	95	106	66	25	380	-.41 (1.20)
e_{41}	12	11	50	164	142	379	1.09 (.95)
e_{42}	24	34	87	132	102	379	.67 (1.15)
e_{51}	7	3	49	140	181	380	1.28 (.85)
e_{52}	11	15	85	153	115	379	.91 (.97)

Appendix table A4.2: Rank scores and some descriptive statistics of the attitudinal beliefs (in_k) and outcome evaluations (m_k)

Ind.	Much against < > Much in favour -2	-1	0	1	2	Obs.	% Obs. *NA*	Mean (SE_M)
in_1	1	0	41	117	188	364	4.7	1.41 (.72)
in_2	3	13	106	56	16	363	46.6	.36 (.79)
in_3	14	11	52	34	82	364	47.0	.82 (1.25)
in_4	10	10	75	83	89	363	25.6	.87 (1.04)
in_5	11	5	115	70	47	364	31.9	.55 (.97)
in_6	4	12	138	129	43	362	9.9	.60 (.81)
in_7	2	7	95	96	128	365	10.1	1.04 (.91)
in_8	11	12	113	52	60	362	31.5	.56 (1.05)
in_9	3	6	117	131	56	365	14.2	.74 (.81)
in_{10}	9	13	153	77	42	367	19.9	.44 (.90)
in_{11}	8	12	79	104	83	364	21.4	.85 (.98)
in_{12}	16	14	94	38	14	367	52.0	.11 (.98)
Ind.	Not important > > Very important 1	2	3	4	5	Obs.	% Obs. *NA*	Mean (SE_M)
m_1	15	14	52	153	128	366	1.1	4.01 (1.01)
m_2	50	41	75	36	9	362	41.7	2.59 (1.15)
m_3	65	23	70	37	39	366	36.1	2.84 (1.42)
m_4	97	63	86	38	19	366	17.2	2.40 (1.23)
m_5	104	55	88	37	17	366	17.8	2.36 (1.23)
m_6	40	33	104	116	49	365	6.3	3.30 (1.18)
m_7	33	23	72	98	118	366	6.0	3.71 (1.27)
m_8	97	53	88	39	21	365	18.4	2.44 (1.26)
m_9	51	33	109	111	33	365	7.7	3.12 (1.19)
m_{10}	73	40	120	64	29	365	10.7	2.80 (1.24)
m_{11}	79	53	96	58	22	364	15.4	2.65 (1.25)
m_{12}	109	25	65	11	8	367	40.6	2.01 (1.16)

Appendix table A4.3: Rank scores and some descriptive statistics of the attitudinal beliefs (dn_l) and outcome evaluations (i_l)

Ind.	Definitely will not < > Definitely will -2	-1	0	1	2	Obs.	% Obs. *NA*	Mean (SE_M)
dn_1	5	5	120	102	69	368	18.2	.75 (.88)
dn_2	6	9	132	60	15	368	39.7	.31 (.77)
dn_3	5	20	165	124	23	369	8.7	.42 (.77)
dn_4	2	13	143	131	36	368	11.7	.57 (.76)
Ind.	Not important > > Very important 1	2	3	4	5	Obs.	% Obs. *NA*	Mean (SE_M)
i_1	114	66	81	59	13	369	9.8	2.37 (1.23)
i_2	80	35	72	45	6	368	35.3	2.42 (1.20)
i_3	74	40	93	111	32	369	5.1	2.96 (1.28)
i_4	99	66	110	55	13	369	9.8	2.47 (1.17)

Appendix table A4.4: Rank scores and some descriptive statistics of the attitudinal beliefs c_{mn} and outcome evaluations p_{mn}.

	Not likely > > Very likely						
Ind.	1	2	3	4	5	Obs.	Mean (*SE_M*)
c_{11}	9	25	68	192	90	384	3.86 (.93)
c_{12}	15	35	109	167	58	384	3.57 (.98)
c_{21}	7	17	60	183	117	384	4.01 (.90)
c_{22}	8	19	65	134	159	385	4.08 (.98)
c_{31}	20	27	99	129	108	383	3.73 (1.10)
c_{32}	17	16	99	101	150	383	3.92 (1.10)
c_{41}	40	71	117	108	49	385	3.14 (1.17)
c_{42}	25	52	152	114	38	381	3.23 (1.02)
c_{51}	56	84	128	86	29	383	2.86 (1.15)
c_{52}	17	26	112	117	113	385	3.74 (1.09)
	Harder / dissuading < > Easier / persuading						
Ind.	-2	-1	0	1	2	Obs.	Mean (SE_M)
p_{11}	12	8	94	170	100	384	.88 (.93)
p_{12}	12	6	66	168	131	383	1.04 (.93)
p_{21}	9	12	90	175	97	383	.89 (.90)
p_{22}	28	41	160	103	51	383	.28 (1.06)
p_{31}	15	17	112	155	85	384	.72 (.98)
p_{32}	17	17	115	152	84	385	.70 (1.00)
p_{41}	11	9	76	193	94	383	.91 (.90)
p_{42}	8	6	71	157	142	384	1.09 (.89)
p_{51}	20	16	106	161	82	385	.70 (1.02)
p_{52}	18	36	148	117	64	383	.45 (1.03)

Chapter 5

Perceived risk and personality traits explaining heterogeneity in Dutch dairy farmers' beliefs about vaccination against bluetongue

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Abstract

When designing effective voluntary vaccination strategies against animal disease epidemics, policy makers need to take into account that different groups of farmers base their participation decisions on different considerations. Using the past bluetongue virus serotype 8 epidemic of 2006 – 2009 in Europe as an example, this paper uses the reasoned action approach to identify a set of attitudinal beliefs being the major drivers behind the intended decision to participate in voluntary vaccination. The results show that there is heterogeneity among farmers in these beliefs. In particular, perceived risk, which was captured by a risk attitude and a risk perception of the farmer, and personality traits are associated with variability in beliefs about vaccination against bluetongue. The patterns found between perceived risk, personality traits and other farm and farmer characteristics were discussed in relation to the governance of animal health.

Keywords

reasoned action approach, beliefs, perceived risk, personality traits, bluetongue, vaccination

5.1 Introduction

Animal health authorities in Europe are increasingly offering reactive voluntary vaccination schemes to farmers in order to prevent the consequences of serious animal health epidemics. Farmers differ in their personal and farm characteristics and are likely having different considerations for participating in such a scheme. Next to economic considerations, these can be intrinsic or social in nature.

One of such serious animal disease epidemics, caused by bluetongue (BT) virus serotype 8, was first reported in Europe in 2006 and ultimately controlled during 2009 after a mass reactive vaccination scheme, primarily directed towards controlling the spread of the virus, at European transnational level was adopted in 2008 (Elbers et al., 2010). A unique factor here was that a few European countries (including England, the Netherlands and Wales) left the decision to vaccinate to the farmers themselves. Most member states (including Belgium, Germany, Luxembourg and the Czech Republic) adopted a mandatory vaccination scheme to meet expected epidemiological goals, i.e. stop the spread of disease and in the end eradicate the disease. France adopted a mixture of voluntary and compulsory schemes (Wilson and Mellor, 2009).

The animal health authorities in the Netherlands thus adopted a voluntary vaccination scheme, thereby possibly losing control on the uptake and becoming dependent on the collective participation response of farmers. The choice for voluntary vaccination schemes took places against a background where governance of animal health is shifting towards a more neoliberal model of cost and responsibility sharing (Enticott et al., 2014; Maye et al., 2014), but also because of non-positive sentiments of cattle farmers with obligatory vaccination campaigns due to a negative experience with a vaccination campaign against Infectious Bovine Rhinotracheitis, when a batch of vaccines was contaminated (Elbers et al., 2010). At the same time, it is agreed world-wide that national governments bear the final responsibility of guaranteeing veterinary, sanitary and phytosanitary safety, including the control of animal diseases such as BT (OIE, 2017).

In the light of the foregoing, voluntary approaches might not meet the required epidemiological goals. On the other hand, if a voluntary approach can meet the epidemiological goals, this has all the intrinsic ingredients for the approach to be more cost-effective and efficient overall (e.g. Segerson, 2013). Farmers' behaviour needs to be understood well before vaccination schemes that trust on voluntary approaches are designed and implemented.

Social behaviour is, according to the reasoned action approach (RAA, Fishbein and Ajzen, 2010), guided by three kinds of considerations: attitudinal, normative and control beliefs. The more favourable the attitude towards the behaviour, the more normative pressure is perceived to perform the behaviour, the more perceived control over the behaviour, the more likely it is that the behaviour is performed. Attitudinal beliefs link the behaviour to outcomes and/or potential consequences (e.g. vaccination insures the risk of infection or gives adverse effects) of the behaviour. Normative beliefs refer to the expectations and perceived behaviour of others. Control beliefs reflect factors that may facilitate or hinder performing of the behaviour. Each farmer forms his or her beliefs in daily encounters in the real world, and in different ways through direct observation (e.g. perceived past experience), external information (e.g. via veterinarians) or through inference processes (e.g. based on another belief that grazing cows increase the probability of infection) (Fishbein and Ajzen, 2010).

When revealing the most influential beliefs using latent variable regression techniques, homogeneity in beliefs among the farmers in the sample was assumed (see Sok et al., 2015). In reality, different groups of farmers base their participation decisions on different considerations. When designing effective vaccination schemes, it is therefore more realistic to assume that farmers are heterogeneous in their beliefs.

Differences in farm-management might partly explain the heterogeneity in beliefs to participate in a reactive vaccination scheme. For example, whether cows are kept inside or graze outside can influence the likelihood of BT virus infection (e.g. Baylis et al., 2010; Santman-Berends et al., 2010). If the heifer management is such that a part of the calves are retained for being exported in addition to the replacement of dairy cows can be a strong economic consideration to vaccinate (Sok et al., 2014). A second group of background variables that can explain heterogeneity in beliefs are so-called behavioural variables. An important concept here is perceived risk in relation to animal disease epidemics, captured by a risk attitude (risk preference) and risk perception of the farmer (Meuwissen et al., 2001; Flaten et al., 2005; Ogurtsov et al., 2009; Valeeva et al., 2011) and personality traits (e.g. Austin et al., 2001).

This paper explores the factors determining heterogeneity in attitudinal beliefs for the participation in voluntary vaccination against BT. It applies a cluster analysis to group farmers based on different sets of scores on attitudinal beliefs. The farmer clusters are profiled using background variables through a multinomial logistic regression model. The profile clusters may contain important information for designing effective vaccination strategies against animal diseases such as BT, where the success of control depends on collective action. The relevancy for policy-making can be shown with the notification that BT (virus serotype 8) re-appeared in France and a vaccination campaign is needed to control the spread (Sailleau et al., 2017).

The remainder of this paper is structured as follows. First, the RAA framework is briefly described and results of preceding related studies that have used the RAA to study BT vaccination behaviour are summarized. Next, in the materials and method section, the two-stage clustering method and the multinomial regression model procedures that are used in this paper are described and the results obtained are presented. The paper ends with a discussion of the results and concluding remarks.

5.2 Framework and previous research

Figure 1 presents the RAA framework graphically. The RAA is the most recent representation of the Theory of Planned Behaviour and the Integrative Model (Fishbein and Ajzen, 2010). It is a decision model from social psychology, and predicts that a given future behaviour is explained by the intention to perform the behaviour. The intention, in turn, is directly explained by four main social-psychological constructs: attitude, perceived norms and perceived behavioural control. Within perceived norms, a distinction is made between injunctive and descriptive norms. In turn, these constructs are explained by underlying beliefs, which are the indirect measures explaining intention.

Figure 1 also shows how this study relates to preceding studies. For each study the aim and scope is clarified. In study 1 Sok et al. (2016b) concluded, among other things, that the farmers' intention to participate in a voluntary hypothetical reactive vaccination scheme when BT were to occur is mainly attitude-driven. Therefore, normative and control beliefs were kept outside the scope of the current study (marked grey in Figure 1).

Since farmers' intentions to participate in a voluntary hypothetical reactive vaccination scheme against BT are mainly attitude-driven, attitudinal beliefs particularly guide the behaviour. These attitudinal beliefs have been identified and elicited during interviews and subsequently analyzed to see which of them explained attitude best (Sok et al., 2015). The most influential attitudinal beliefs (indicated in Figure 1 with the number of plusses or minuses) related to positive outcomes of the behaviour, i.e. being insured against the risk of economic damage as a result of a BT infection (*Economic risk insurance*) and being insured against the risk of being emotionally confronted with harrowing disease cases, cows seriously suffering from BT (*Job satisfaction* or 'psychological insurance').

Another positive outcome but less influential is that with vaccination a contribution is made to the eradication of the disease (*Collective disease eradication*). There were also two negative outcomes but less influential in explaining attitude. One related to the perception that vaccination could lead to potential adverse effects and/or stress in the herd (*Production distortions)* and the other related to the time and effort it takes to get the herd vaccinated (*Time and effort*).

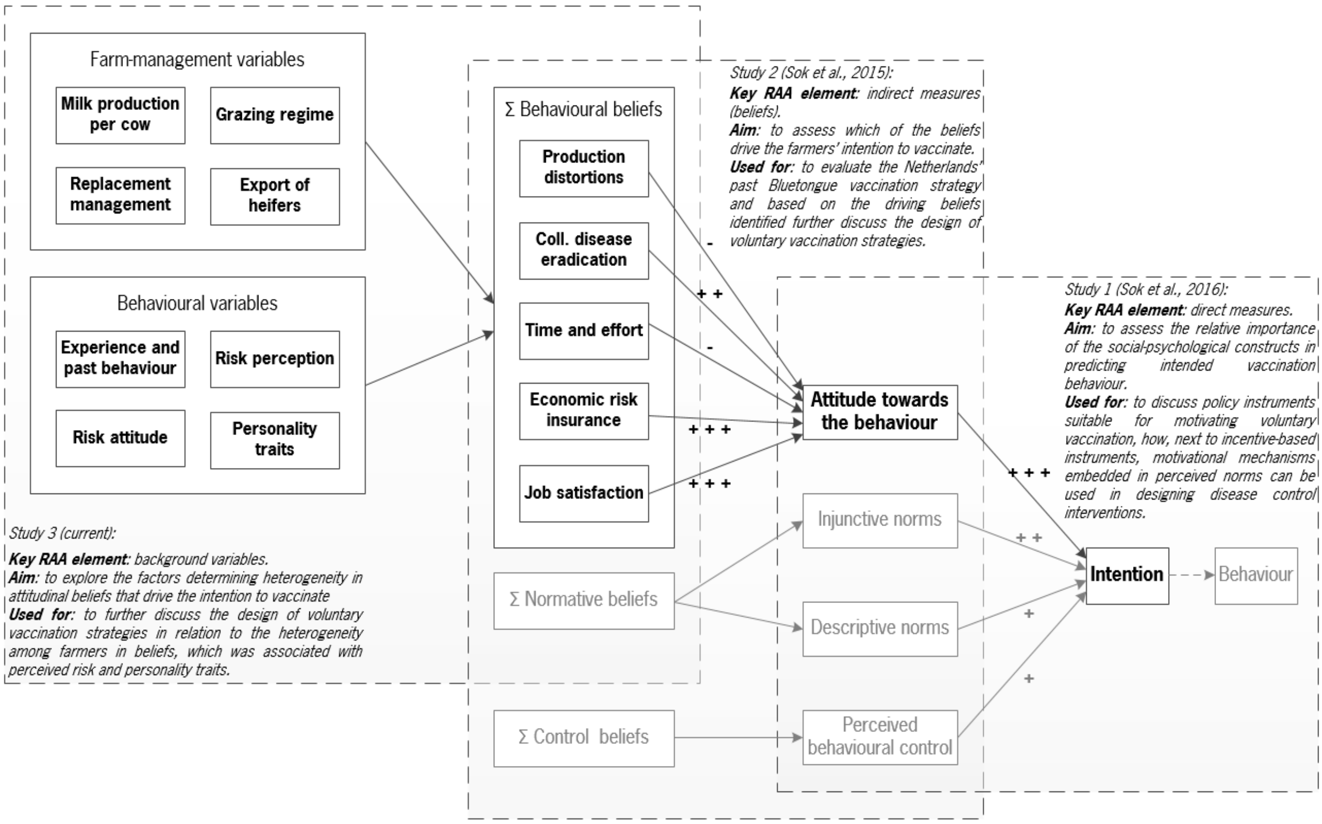

Figure 5-1: The reasoned action approach, adapted from Fishbein and Ajzen (2010).

5.3 Materials and methods

5.3.1 Questionnaire and sample

A major part of the 12-page questionnaire was used to obtain direct and indirect measures of the social-psychological constructs as specified in the RAA framework (see Figure 1). Details regarding the measurement and statistical analyses are found in Sok et al. (2015; 2016b). Part of the questionnaire[6] was reserved for measuring the background variables for the current study, i.e. variables that can explain the adoption profile of groups of farmers.

Background variables were classified into farm-management and behavioural variables (see Figure 1). In the group of farm-management variables, average milk production per cow (305 days) was measured with three categories: 'less than 8500 kg'., 'between 8500 – 9500 kg.' and 'more than 9500 kg.'. Furthermore, three management characteristics were measured, relating to grazing, replacement and export. The grazing regime was measured with three categories: 'never grazing', 'part of the day' and 'day and night'. Replacement management was measured with five categories ranging from 'entirely own raised' to 'entirely purchased'. Sale of breeding stock was measured with three categories: 'never', 'occasionally' and 'regularly'. A composite variable was constructed from the variables relating to import (replacement management) and export of heifers. The first category consisted of farms that rear their own heifers, and never export them. The second category consisted of farms that occasionally import and/or export heifers. The third and last category consisted of farms that regularly import and/or export heifers.

In the group of behavioural variables, a sub-classification was made into perceived past experience, perceived risk and personality traits. In the subgroup of perceived past experience variables, the respondent was asked whether he or she thought that bluetongue occurred at the farm in the past and that the herd had been vaccinated against bluetongue, the latter representing (perceived) past behaviour. Both were measured on a 4-point Likert type scale with categories: 'Certainly not', 'Probably not', 'Probably yes' and 'Certainly yes'. In the subgroup of perceived risk variables, a risk perception and a relative risk attitude were measured. The conceptual framework for measuring risk is taken from the Health Belief Model, where risk perception is defined as a composite of perceived susceptibility times perceived impact (Janz and Becker, 1984; Valeeva et al., 2011). Risk perception was measured with two 5-point Likert-type scales, one with adjectives 'Never' to 'Often' and one with adjectives 'No impact' to 'High impact'. The relative risk attitude (with

[6] The questionnaire is available upon request.

respect to animal diseases in general) was measured on a 5-point Likert type scale with adjectives 'Less risk' to 'More risk' (see Meuwissen et al., 2001). In the subgroup of personality traits variables, the Big Five personality dimensions were measured, namely agreeableness, conscientiousness, emotional stability, extraversion and openness. A brief measure is the Ten-Item Personality Inventory (TIPI), developed by Gosling et al. (2003), which was applied using a calibrated Dutch questionnaire (Hofmans et al., 2008).

Based on an expected response rate of 20 – 25% and a minimum sample size of 300, the survey was randomly sent to 1,500 Dutch dairy farmers. This sample was drawn from the National Cattle Identification and Registration Database and restricted to farms with a herd size of at least 40 dairy cows. The latter was done to ensure that hobby holders were not included, as they likely have a different set of arguments in favour or against vaccination. Some socio-demographic variables and other farm characteristics were additionally measured to check for the sample representativeness.

The questionnaire, along with a pre-paid return envelope and an accompanying letter, was sent out in the second week of January 2014. Farmers were offered two possibilities to fill in the questionnaire, i.e. using the paper copy, or an on-line survey. Each respondent had a 10% chance of winning a gift coupon of € 25. After 4 weeks, a reminder was sent to all farmers in the sample. The final response, the 415th, was returned around mid-March, resulting in a response rate of almost 28%.

5.3.2 Cluster analysis

Cluster analysis is an exploratory multivariate statistical technique, and was used here to decompose the single cluster of farmers into multiple clusters such that, within clusters, farmers would be as much as possible homogeneous, and between clusters as much as possible heterogeneous in their attitudinal beliefs.

The attitudinal beliefs were tested for multicollinearity. The highest variance inflation factor (VIF) was found in the linear regression with the belief *Job satisfaction* as the dependent variable and all other attitudinal beliefs as independent variables, which was 1.81. Kline (2011) indicates that a VIF of >10 is indicating that variables may be redundant.

Specifically, a two-stage cluster analysis procedure was used (e.g. Punj and Stewart, 1983; Ketchen and Shook, 1996). In the first stage, a proximity matrix was made based on Manhattan distance measure between each pair of farmers (clusters); the distance is defined as the sum of the absolute differences of each of the five attitudinal beliefs. The Ward's minimum variance method takes the proximity matrix and groups each time the pair of clusters with the smallest distance, till only one cluster is left. The number of clusters was based on the minimum of the total within-cluster variance (sum of squares).

The final number of clusters was determined using precision and usefulness as criteria. More clusters will better represent the heterogeneity in attitudinal beliefs, but too many clusters will complicate further analysis with the regression model used for predicting a farmer cluster membership. Precision was assessed by looking at the dendogram and stopping rules provided by Stata 13. Usefulness was assessed by looking at the cluster sizes and interpretability of the results.

In the second stage, the clusters were refined using the K-means method; the resulting cluster means were taken from the Ward's method and all cases were reassigned in an iterative way to the cluster mean that is the closest.

Validity of the clusters was assessed by taking the direct attitude and intention measures (see Framework section). According to the theory and previous results, farmers in a cluster with high (low) scores on favourable outcomes should also have high (low) scores on attitude and intention measures. Furthermore, one-way ANOVAs tests were run on the within-cluster means of the five attitudinal beliefs.

5.3.3 Statistical analysis

The first step in the statistical analysis was to recode some of the variables. The group of farm-management variables was measured as categorical variables, and were recoded into dummies. The behavioural variables were measured using Likert-type scales and were left unchanged, except the perceived past experience variables. The scales 'Certainly […]' and 'Probably […]' of this variable were transformed into a dummy variable (see Table 2).

Several tests were run to see which variables in the regression model likely explain why farmers ended up in a particular cluster. For dummy variables, contingency tables with a chi-square (χ^2) measure of association were run to test, based on the cluster analysis results, whether within-cluster means are significantly different from each other. For continuous variables, one-way ANOVAs were run.

The obtained cluster variable is the dependent variable in the multinomial logistic regression model and the selected background variables are the independent variables. The model is defined as:

$$P(y_i = j) = \beta'_j x_i + \varepsilon_i \ \ (j = 1, 2, \dots, M) \qquad (1)$$

where y_i is the probability that farmer i belongs to cluster j. The row vector x_i is made up of independent variables of the farm-management and behavioural variables, the column vector β'_j are the unknown regressions coefficients that need to be estimated using maximum likelihood estimation, and ε_i is the error term.

Given that the dependent is a categorical variable with M levels, the error term is logistic. The probability that farmer i belongs e.g. to cluster 1 is:

$$P(y_i = 1) = \frac{exp(\beta'_1 x_i)}{1+exp(\beta'_2 x_i)+\dots+exp(\beta'_M x_i)}. \qquad (2)$$

Model fit is assessed with the log-likelihood ratio test and the pseudo-R^2 of McFadden. Effect sizes of the regression coefficients are analyzed with the marginal effects, specifically the average marginal effect (AME) using Stata's margins command (Mood, 2010). For dummy variables, the AME gives the predicted change in probability of the cluster variable given the discrete change, averaged across the observations with other variables held constant (conditional). For continuous variables, it is the predicted change in probability of the cluster variable given a one unit change.

5.4 Results

5.4.1 Sample representativeness

The average age of the respondent was 49 years. Nearly two third of respondents had an intermediate vocational education background and one fifth had some form of higher professional education qualification.

Table 2 shows the overall mean (third column) of the background variables. Milk production (305 days lactation) varied widely, about 40 per cent of the farmers fell in the category '< 8500 kg' and 40 per cent in the category '8500 – 9500'. Almost 80 per cent of the respondents indicated they let their animals graze, of whom three quarters grazes for only a part of the day. About half of all respondents indicated they sometimes export breeding cattle and almost 20 per cent does this regularly. Furthermore, the average herd size in the sample was 94 dairy cows and 69 young stock.

The average score on herd size and grazing regime in the sample were in line with the statistics provided by the Agricultural Economic Institute (LEI, 2016). Their reported mean herd size is 93 in 2013 and 95 cows in 2014. The grazing regime for three time slices (average of May, July and September) is 35% “Cows in the shed”, 51% “Restricted grazing” and 14% “Unrestricted grazing”. Statistics from the Cattle Improvement Co-operative (CRV, 2014) estimated the average milk production in the Netherlands (305 days lactation) at 8523 kg. For age, education and export of breeding cattle no comparisons with official data could be made. However, based on the measures for which comparison is possible, the sample appeared to be a good representation of the Dutch dairy farmers population (i.e. those with at least 40 dairy cows).

5.4.2 Description of the clusters

The upper part (*Belief*) of Table 1 shows the result of the second step of the two-stage cluster analysis. The overall mean is shown as well as the within-cluster centred means are provided. The (normal) mean of a belief of a particular group is obtained by adding the centred mean to the overall mean, for example for group 1 for *Production distortions*, the normal mean is 1.21 + -0.07. In the last two columns, the results of one-way ANOVAs show that the means of the attitudinal beliefs were statistically different between the four clusters for each of the five clustering variables; All beliefs were highly significant at the 0.1% critical level.

The lower part of Table 1 shows the descriptive statistics in terms of the overall mean and within-cluster centred means of four direct attitude and two intention measures. The means were significantly different between the four clusters at the 0.1 per cent critical level.

The cluster analysis suggested four clusters with distinct sets of attitudinal beliefs. The belief *Economic risk insurance* got the highest F value, indicating that this was the most discriminating variable among the clusters identified.

Farmers in cluster 1 represented about one fourth of the sample and are likely less willing to vaccinate given the fairly below average scores on attitude and intention. They had far below average scores on the positive outcomes of the behaviour: *Economic risk insurance*, *Job satisfaction*, and *Collective disease eradication*. Hereafter they are referred to as ‘*non-intenders*’.

Table 5-1: Overall mean and within-group centred means of the attitudinal beliefs, attitude and intention measures

	Range	Overall	Cluster 1	Cluster 2	Cluster 3	Cluster 4	*F*-test[a]
			Non-intenders	*Undecided*	*Intenders1*	*Intenders2*	
		N=367	*N* = 90	*N* = 140	*N* = 53	*N* = 84	
Belief							
Production distortions	-10 – 10	1.21	-0.07	1.31	-7.21	2.44	117.67
Coll. disease eradication	-10 – 10	2.72	-3.60	0.44	1.63	2.10	71.38
Time and effort	-10 – 10	-2.01	0.65	1.53	-2.72	-1.54	23.99
Economic risk insurance	-10 – 10	4.69	-4.03	-1.00	2.65	4.32	192.01
Job satisfaction	-10 – 10	4.02	-3.06	-0.30	1.41	2.89	127.30
Attitude towards vaccination							
(un)satisfying	1 – 5	3.63	-0.98	-0.04	0.64	0.72	58.27
(dis)advantageous	1 – 5	3.56	-0.86	-0.02	0.56	0.60	51.79
(un)necessary	1 – 5	3.58	-0.82	-0.07	0.75	0.53	41.04
(un)important	1 – 5	3.76	-0.94	-0.03	0.68	0.63	59.48
Intention to vaccinate							
I intend to	1 – 5	3.21	-0.98	-0.05	0.77	0.64	44.37
I am willing to	1 – 5	3.43	-0.87	-0.01	0.70	0.50	33.53

[a] The differences between the clusters of the within-group centred means of all variables were highly significant at the 0.1% level.

Cluster 2 was the largest cluster, representing almost 40 per cent of the farmers in the sample. This cluster can be seen as the average cluster since their attitude and intention are about equal to the overall mean. Also the attitudinal beliefs did not deviate much from the overall mean. Farmers in this cluster did not clearly indicate whether they want to have their herd vaccinated. Hereafter they are referred to as '*undecided*'.

Farmers in cluster 3 represented about one seventh of the sample, and were characterized by well above average scores on the three positive outcomes of the behaviour and in particular by a far below average score on *Production distortions*. These farmers are expected to be willing to vaccinate since the intention scores were about 4 on a scale of 1 to 5. Hereafter they are referred to as '*intenders1*'.

Just as in cluster 3, farmers in cluster 4 had high attitude and intention scores. They scored well above average on the three positive outcomes, in particular *Economic risk insurance* with a mean of 9.01 on a scale of -10 to 10. What distinguishes farmers in cluster 4 from those in cluster 3 was the above average score on *Production distortions*. Hereafter they are referred to as '*intenders2*'.

5.4.3 Description of the background variables

Table 2 gives an overview of the background variables considered. The significance levels from the chi-square and one-way ANOVA tests (see section 2.4) are indicated with the asterisks behind each variable.

In the group of farm-management variables, (part of) the variables relating to milk production and heifer management were significantly associated with the cluster variable, at least at the 10 per cent level. Milk production per cow varied among the clusters, with lower production levels especially present in the *non-intenders group* and higher production levels in the *intenders2* group. Farmers in the *intenders1* group more often imported or exported heifers.

In the group of behavioural variables, again, most of the variables were significantly associated with the cluster variable, at least at the 10 per cent critical level, except some of the personality traits. Only the trait emotional stability was clearly not significantly associated with the cluster, the others were (extraversion and openness) almost significant at the 10 per cent critical level.

Regarding the perceived past experiences, farmers were more explicit about whether they vaccinated against BT in the past than whether BT occurred at their farm. Most farmers reported either ‘probably not’ or ‘probably yes’ for the BT infection experience, while for the BT vaccination experience, most farmers reported either ‘certainly not’ or ‘certainly yes’. Almost 60 per cent of the farmers in the *non-intenders* group perceived that BT did not occur at their farm while in both *intenders* groups this was exactly the opposite. Almost 70 per cent of the farmers in the *non-intenders group* perceived that they did not vaccinate against BT while in the both *intenders* groups this was exactly the opposite.

Regarding the perceived risk, a first observation is that, with increasing risk perception, farmers were more risk averse. Farmers in the *non-intenders* group had the lowest risk perception and at the same time were, on average, willing to take more risk than their colleague farmers. Farmers in both *intenders* groups, on the other hand, were willing to take less risk and had higher risk perception scores, especially those in the *intenders2* group.

Regarding the personality traits, farmers in the *non-intenders* group scored, on average, the lowest on agreeableness and conscientiousness and the highest on openness, while this was exactly the opposite for farmers in both *intenders* groups. Farmers in the *undecided* group scored, on average, the lowest on emotional stability and extraversion.

Table 5-2: Overview of the background variables in terms of their description, range, overall and group-mean.

Background variable	Range	Overall	*Non-intenders*	*Undecided*	*Intenders1*	*Intenders2*
Farm-management characteristics						
Milk production < 8500 kg.***	0 to 1	0.44	0.60	0.49	0.34	0.25
Milk production 8500-9500 kg.*	0 to 1	0.40	0.32	0.38	0.47	0.49
Milk production > 9500 kg.**	0 to 1	0.16	0.08	0.14	0.19	0.25
Grazing none	0 to 1	0.20	0.22	0.19	0.25	0.17
Grazing part of the day	0 to 1	0.60	0.52	0.61	0.58	0.70
Grazing day and night	0 to 1	0.19	0.26	0.20	0.17	0.13
Own raised heifers and no export	0 to 1	0.31	0.29	0.26	0.13	0.20
Occasionally import/export heifers	0 to 1	0.50	0.47	0.59	0.53	0.57
Regularly import/export heifers**	0 to 1	0.19	0.24	0.16	0.34	0.23
Behavioural characteristics						
Perceived past experience						
Bluetongue infected in past**	0 to 1	0.53	0.42	0.53	0.59	0.63
Bluetongue vaccinated in past***	0 to 1	0.54	0.32	0.53	0.70	0.70
Perceived risk						
Risk perception***	1 to 25	8.16	6.29	7.93	8.40	10.37
Relative risk attitude***	1 to 5	2.66	3.21	2.70	2.29	2.23
Personality traits						
Agreeableness**	1 to 7	5.59	5.37	5.56	5.78	5.75
Emotional stability	1 to 7	5.54	5.55	5.45	5.75	5.54
Extraversion	1 to 7	4.97	5.06	4.78	4.99	5.17
Conscientiousness***	1 to 7	5.36	5.09	5.24	5.60	5.71
Openness	1 to 7	4.97	5.10	5.06	4.85	4.76

*, ** and *** indicate significance level at 0.10 (highly), 0.05 (moderately) and 0.01 (somewhat) respectively.

5.4.4 Regression results

Table 3 presents the average marginal effects that were computed from the multinomial logistic model. The dummy variables relating to grazing were excluded from the analysis since they had low associations with the cluster variable. The personality trait of emotional stability was removed for the same reason. One of the milk production and heifer management variables were also excluded to prevent perfect collinearity.

The results on the model fit were as follows. The log-likelihood ratio test was highly significant, indicating that the specified model performed better than a model with just a constant. The McFadden's pseudo-R^2 value of 0.155. According to the empirical relationship found between McFadden's pseudo-R^2 and the R^2 of a linear regression model, the number is equivalent to a R^2 between 0.30 and 0.40 (Domencich and McFadden, 1975, p. 124).

Table 5-3: Estimated average marginal effects of the background factors from the multinomial logistic regression model.

Background variable	$P(y_i = 1)$ *Non-intenders*	$P(y_i = 2)$ *Undecided*	$P(y_i = 3)$ *Intenders1*	$P(y_i = 4)$ *Intenders2*
Milk production 8500-9500 kg.	-.070	-.088	.035	.123***
Milk production > 9500 kg	-.169***	.022	-.000	.147**
Occasionally import/export heifers	-.054	.002	.045	.007
Regularly import/export heifers	.106	-.144*	.106*	-.069
Bluetongue infected in the past	-.031	.006	.021	.003
Bluetongue vaccinated in the past	-.093**	-.027	.090**	.030
Risk perception	-.015***	.001	-.004	.018***
Relative risk attitude	.067***	-.009	-.020	-.038*
Agreeableness	-.041**	.001	.020	.021
Extraversion	.028	-.068***	.002	.038*
Conscientiousness	-.032	-.048*	.035*	.046**
Openness	.025	.053**	-.027*	-.051***

*, ** and *** indicate significance level at 0.10 (highly), 0.05 (moderately) and 0.01 (somewhat) respectively.
N = 346, Log-likelihood value: -387.83, Log-likelihood ratio: 142.22 ($p < 0.001$), McFadden's pseudo-R^2: 0.155.

Within each cluster, the number of asterisks indicates the significance level (highly, moderately or somewhat) of the background variables that were highly associated. In the following paragraphs, they are discussed in relation to the dependent cluster variable, which represent a farmer cluster with each a different set of scores on the five attitudinal beliefs.

The interpretation of an AME in case of a dummy variable, e.g. the variable 'Milk production > 9500 kg.' is as follows. If the milk production level is >9500 kg., it increases the probability of a farm to be in the *intenders2* group by 14.7 per cent. The interpretation of an AME in case of a continuous variable, e.g. the variable 'Risk perception' is slightly different. A one unit increase on the scale of 25 of 'Risk perception' decreases the probability of a farm to be in the *non-intenders* group by 1.5 per cent while it increases the probability to be in the *intenders2* group by 1.8 per cent.

Regarding the farm-management variables, farms with higher milk production levels were more likely in the *intenders2* group as these variables had positive signs and were moderately to highly significant. Farms with lower production levels were more likely in the *non-intenders* group given the negative signs. Farmers that import (for replacement) and/or export heifers were more likely to be in the *intenders1* group, as the heifer management variables included had positive signs and the second was somewhat significant. This likely is the opposite for those in the *undecided* group, with the second variable negative and somewhat significant.

Among the behavioural variables, the perceived BT infection experience did not discriminate among clusters. Farmers who perceived that they vaccinated in the past against BT were, ceteris paribus, less likely part of the *non-intenders* group, while more likely to be situated in the *intenders1* group. The perceived risk measures were particularly associated with the clusters 1 and 4. Farmers who had a low perception of the risk and were willing to take more risk than other farmers were more likely allocated to the *non-intenders* group while the opposite was true for those in the *intenders2* group.

Also different personality traits profiled different clusters. Less agreeable farmers were more likely in the *non-intenders* group. The same line of reasoning applied to the other personality traits as well. Less extraverted farmers were more likely in the *undecided* group while more extraverted farmers were more likely in the *intenders2* group. Less conscientious farmers were more likely in the *undecided* group while more conscientious were more likely in both *intenders* groups. Finally, more 'open' farmers were more likely part of the *undecided* group while less 'open' farmers were more likely to be situated in both *intenders* groups.

5.5 Discussion

This study investigated in particular the heterogeneity in attitudinal beliefs among farmers regarding vaccination against BT by firstly clustering them, and then predicting cluster membership using different background variables. Two groups of background variables have been considered, i.e. farm-management and behavioural variables. The remainder of this section discusses the results of the cluster and regression analysis, paying in particular attention to the roles of perceived risk and personality traits.

Farmers in the *non-intenders* group showed an unfavourable attitude towards participation in a reactive vaccination scheme if BT were to occur. This goes hand in hand with lower milk production levels, lower perceived risk in terms of lower risk perception and higher relative risk attitude. They did not vaccinate during the last BT (virus serotype 8) 2006 – 2009 epidemic. Moreover, they scored significantly lower on the agreeableness trait. According to Nuthall (2009), 'a person classified as being 'agreeable' is good-natured, soft-hearted and somewhat selfless. Generally these people might be called benign and seldom get angry or overly excited about issues. At the other end of the spectrum, a 'non-agreeable' person will be rather irritable, and certainly ruthless as well as being somewhat selfish. All these background variables together provide a consistent profile of a cluster of farmers that is likely not going to vaccinate if bluetongue were to occur.

Farmers in the *undecided* group showed a neutral attitude towards participation in a reactive vaccination scheme if BT were to occur. Both the farmers in the *non-intenders* as well as in the *undecided* group might be so-called hard-to-reach farmers. Using two continua, farmers' (dis)trust in external information sources and their orientation toward the outside world, Jansen et al. (2010) further classified hard-to-reach farmers into proactivists, do-it-yourselfers, wait-and-see-ers, and reclusive traditionalists. Among those different groups of farmers there will exist different considerations not (yet) to participate that can be next to economic relating to intrinsic and social considerations.

Farmers in both *intenders* groups had a favourable attitude towards participation in a vaccination scheme if BT were to occur. These groups differed particularly in terms of their concern about production distortions. The results suggest that the latter goes hand in hand with more intensive farming, in terms of milk production. This explains why farmers in the *intenders2* group perceived the risk of a BT infection to be high in terms of susceptibility and impact, and were willing to take less risks. A valid explanation why farmers in the *intenders1* group were not concerned about production distortions is their (positive) perceived past experience with vaccination during the BT (virus serotype 8) epidemic from 2006 – 2009. Farmers in the *intenders1* group also imported and/or exported heifers more often.

Perceived risk measures in this study were highly associated with the *non-intenders* group and the *intenders2* group. They relate with the intensity of dairy farming, in terms of milk production. This suggests that farmers in particular are concerned about the risk related to the production domain (Meuwissen et al., 2001; Hardaker et al., 2015), and explains why farmers in the *non-intenders* group scored the lowest and farmers in the *intenders2* group scored the highest on the belief *Risk insurance*. These differences in perceived risk also indicate that farmers might not be commonly risk averse, as is often assumed (Ogurtsov et al., 2009; Hardaker et al., 2015). However, farmers' preferences for risk are also domain-specific (Weber et al., 2002; Hansson and Lagerkvist, 2012).

Different (combinations of) personality traits in this study were highly associated with all clusters. One overall pattern observed is that conscientiousness discriminates farmers into higher intenders and lower intenders. According to Nuthall (2009), 'someone who has a high rating on this trait will be careful, reliable and takes responsibility seriously. Such people can generally be relied upon, and when a task is agreed you can be sure it will get done. In contrast, someone who exhibits the other end of this trait's scale will be somewhat careless, undependable and even negligent'. It remains somewhat unclear how conscientiousness relates to the decision problem under study, as it can both be a sense of duty (other-centred motive) and/or achievement striving (self-centred motive) (Moon, 2001; Moon et al., 2012). Another observed pattern holds for the openness trait, with less 'open' farmers in the *intenders* groups and more 'open' farmers in the *non-intenders* and *undecided* group. According to Nuthall (2009), an open person will be daring, liberal and somewhat original in their thinking. In contrast, a person who scores poorly on the openness scale will be conservative, unadventurous and conventional. Austin et al. (2001) found that Scottish production-oriented farmers score highly on extraversion, openness and conscientiousness. This implies that farmers in the *intenders* groups, who reported high intentions to vaccinate, run their farm in a more conservative way, which contradicts with the results of Austin et al. (2001). Moreover, the farm-management variables measured indicate these farmers to be more production-oriented given the higher milk production levels. However, the lower openness scores may also indicate that these farmers are not open to the different decision options in case of animal disease epidemics and seek certainty of protection of their animals, and therefore are favourable towards vaccination. In this sense the openness trait might be decision domain-specific, i.e. with respect to animal disease epidemics these farmers are less 'open', while for other domains they might be more 'open'.

This research shows that in particular perceived risk and personality traits measures can address the heterogeneity in attitudinal beliefs about participation in a reactive vaccination scheme when BT were to occur. Both, perceived risk and personality traits measures, do not seem to be mutually exclusive, they likely somehow interact with each other (Nicholson et al., 2005; Soane and Chmiel, 2005). Dimensions of general trust and confidence, especially in the governance of animal health, also likely play a role here (Siegrist et al., 2005; Enticott et al., 2014).

Furthermore, as farmers are faced with different types and sources of risk, likely the domain-specificity also plays a role. The type of disease is an important factor in how farmers perceive risk. Endemic diseases might be seen as an operational risk while epidemic diseases as a catastrophic risk (Valeeva et al., 2011). BT in north-western Europe in 2006 was defined as an emergent disease in this zone (Saegerman et al., 2008). Future research could further unravel farmers' decision-making in the context of animal health and investigate whether farmers treat this as a risk domain on its own, and also how prevention and control decisions relate with personality traits such as openness and conscientiousness.

When developing effective voluntary vaccination strategies against animal disease epidemics like the past BT epidemic from 2006 – 2009, policy makers need to account for heterogeneity among farmers in internal motivations to participate. Some farmers might be more concerned about the adverse effects of vaccination while others by any means want to have their herd vaccinated to be protected against the economic risk (e.g. Elbers et al., 2010; Gethmann et al., 2015; Sok et al., 2015). The results of this study suggest that about 40 per cent of the farmers, both the *intenders* groups, are internally motivated, and about 25 per cent of the farmers, the *non-intenders* group, are not internally motivated to participate in a voluntary vaccination scheme. For the remaining farmers, the *undecided* group, it is less clear what they will ultimately decide.

The cross-sectional properties of the data makes estimations of participation rates in future voluntary vaccination schemes precarious. Given the current presence of bluetongue in France, the current perceived risk of the respondents might be higher compared to the moment the perceived risk was measured in the questionnaire. All other behavioural and farm-management variables measured in this questionnaire can assumed to be stable over time, at least in the short run. The clusters of farmers who are internally motivated might very well represent the group that coincides with the lower limit of participation (40% of the total population of farmers), as at the time of the data collection there was no real threat of BT. Gethmann et al. (2015) reported that 40.7% of German cattle farmers' expressed the intention to vaccinate in 2011 (questionnaire undertaken in 2010). Elbers et al. (2010) reported that 52% if Dutch dairy farmers indicated to be willing to vaccinate their herd against other BT serotypes in the future if vaccines were made available (questionnaire undertaken in 2009). The effectiveness of voluntary vaccination schemes depend on the extent to which those farmers who are not internally motivated or are undecided can be convinced. Different types of policy instruments exist that can induce voluntary behaviour via internal or external motivation.

Chapter 6

Farmers' preferences for bluetongue vaccination scheme attributes: An integrated choice and latent variable approach

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Abstract

Re-emergence of the bluetongue disease in Europe poses a continuous threat to European livestock production. Large-scale vaccination is the most effective intervention to control virus spread. Compared to command-and-control approaches, voluntary vaccination approaches can be effective at lower costs, provided that farmers are willing to participate. We use a discrete choice experiment to estimate the preferences for vaccination scheme attributes, accounting for preference heterogeneity via an integrated choice and latent variable approach. In designing livestock disease control schemes, it is often argued that governments should use financial, incentive-based policy instruments to compensate farmers for externalities, assuming they act in rational self-interest. Our results suggest that in addition to economic motives, farmers can have intrinsic or social motives to invest in livestock disease control. Implications for the effectiveness of providing subsidy or information to motivate voluntary participation are discussed.

Keywords

Livestock disease control, policy instruments, voluntary vaccination, bluetongue, integrated choice and latent variable model, preference heterogeneity, attitude, perceived norms

6.1 Introduction

Bluetongue is a vector-borne livestock disease caused by the bluetongue virus, and has been identified on all continents except Antarctica. Biting midges (*Culicoides* spp.) transmit the virus from infected to susceptible ruminants (Maclachlan, 2011). An outbreak of an vector-borne disease can have large socio-economic consequences, in terms of livestock production, policy and trade in the countries or regions affected (Burrell, 2002). A large epidemic of bluetongue virus serotype 8 occurred in Europe during 2006 to 2009. Several years later, multiple outbreaks were reported in France in the autumn of 2015 (Sailleau et al., 2017). Re-emergence of bluetongue in Europe poses a continuous threat for livestock production. Large-scale vaccination is the most effective intervention to control the spread (e.g. Wilson and Mellor, 2009).

Livestock disease control policies have traditionally followed a command-and-control approach of regulation and enforcement, but voluntary approaches are now also being considered. During the bluetongue virus serotype 8 epidemic in 2006 to 2009, some European Union member states adopted voluntary vaccination schemes (Wilson and Mellor, 2009). Outbreaks in France continued to be reported in 2016 and animal health authorities in the UK have been considering whether vaccination strategies should be implemented, and in what form (Bessell et al., 2016; Roberts et al., 2016). Voluntary approaches are more flexible in terms of legislation and can also be effective at lower costs, provided that farmers are willing to participate (Segerson, 2013).

Theoretical economic studies that take into account the endogenous nature of infection risk, predict that farmers are likely to underinvest in private disease control measures compared to a social welfare optimum because of the presence of externalities (e.g. Beach et al., 2007; Rat-Aspert and Fourichon, 2010; Gramig and Horan, 2011; Zilberman et al., 2012), since vaccination helps a region become disease free, while no vaccination contributes to disease transmission. Public intervention may be justified when such market failures occur. Other market failures arise from information asymmetries, resulting in moral hazard and adverse selection problems (e.g. Gramig et al., 2009; Hennessy and Wolf, 2015).

These studies mentioned previously focused on the design and use of financial, incentive-based policy instruments to compensate for externalities. The farmer's decision-making process is modelled as a "black box", which does not consider how preferences are formed and choices are made (Ben-Akiva et al., 1999; McFadden, 1999) and are limited in their ability to account for process and context in decision making, failing to account for heterogeneity in decision making among farmers. If the willingness to invest in vaccination is also driven by intrinsic and social motives, this could imply that a mix of policy instruments, rather than simply financial compensation, is needed to make voluntary approaches more effective (Barnes et al., 2015; Ochieng' and Hobbs, 2016).

A complementary body of literature focuses on the identification and assessment of key factors that influence decision making on livestock disease control, using qualitative and quantitative research methods. In addition to instrumental considerations (e.g. private risks and income effects), the experiential consequences of disease control decisions are important for many farmers (Elbers et al., 2010; Gethmann et al., 2015; Sok et al., 2015). In the economic literature, these are described as non-use or passive values (e.g. Hansson and Lagerkvist, 2015; Schreiner and Hess, 2016) or nonpecuniary benefits (Howley, 2015). Another key factor is that private decisions could be influenced by social pressures through different types of perceived norms (Jones et al., 2015; Vande Velde et al., 2015; Sok et al., 2016b). Furthermore, it is important to account for specific perceptions about disease risk, about the safety and effectiveness of applied measures and about the trust and confidence in the disease control approach chosen by animal health authorities (e.g. Perry et al., 2001; Flaten et al., 2005; Heffernan et al., 2008; Palmer et al., 2009; Valeeva et al., 2011; Schemann et al., 2012; Toma et al., 2013; Alarcon et al., 2014; Enticott et al., 2014; Maye et al., 2014; Sok et al., 2016a).

Several authors in the domain of economics of animal health have suggested complementing economic theory with insights from behavioural sciences to improve the understanding of livestock disease control decisions, to identify ways of motivating farmers to comply with voluntary approaches (Barnes et al., 2015; Gilbert and Rushton, 2016). It would be useful to develop and test a utility model representation of farmers' behaviour that allows for heterogeneity in the motives to invest in disease control, before further studying the dynamic interactions between farmers' collective behaviour and disease epidemiology. Given the nature of disease control efforts as public goods and the presence of non-use values in decision making, a stated preference approach can assess farmers' preferences for different attributes of livestock disease control policies (Adamowicz et al., 1998). In addition to instrumental attributes, such as the vaccine effectiveness or costs (Bennett and Balcombe, 2012), key factors that were previously described can help in defining other attributes that are important for policy making.

This study has two objectives: first, to assess farmers' preferences for policy-related attributes of a bluetongue vaccination scheme; second, to improve the understanding of the factors underlying the behavioural heterogeneity in farmers' preferences for these attributes. We use a survey-based discrete choice experiment to derive farmers' marginal utilities of attributes of public voluntary bluetongue vaccination schemes. Heterogeneity in preferences for attributes is commonly modelled via unobserved random effects (McFadden and Train, 2000; Hensher and Greene, 2003) and readily observable and relatively objective characteristics. More recently, preference heterogeneity is partially modelled using latent constructs from social psychology to enhance the behavioural representation in choice models. Such models have been mainly developed in the marketing and transport literature, where they are known as the hybrid choice model or integrated choice and latent variable model (ICLV) (e.g. Ben-Akiva et al., 2012; Hildebrandt et al., 2012). The ICLV model offers a general econometric framework to supplement economic theory with concepts or theories from other social sciences (Walker and Ben-Akiva, 2002; Walker et al., 2007). We use the ICLV approach to incorporate preferences for attributes, latent social-psychological constructs in addition to readily observable farm and farmer characteristics.

6.2 Framework: Integrated choice and latent variable model

The vaccination choice is formulated as a discrete choice problem, which is consistent with random utility theory and various econometric models. Vaccination schemes differ in terms of a few choice attributes. The utility derived from a vaccination scheme is the sum of the utilities derived from the choice attributes (Lancaster, 1966). Faced with alternative vaccination schemes, farmers are presumed to choose the alternative (or the option to not vaccinate) that is likely to give them the highest utility.

The standard approach in econometrics to account for heterogeneity in preferences is to include a random component using a mixed logit model specification (McFadden and Train, 2000; Hensher and Greene, 2003) and readily observable and relatively objective characteristics. In the mixed logit model, the utilities of the choice attributes are assumed to vary across farmers according to some pre-specified (usually normal) distribution and the sufficient statistics describing the distribution are estimated (for a normal distribution: the mean and the standard deviation). If the estimated standard deviations are significant, statistical unobserved heterogeneity in preferences is present. However, as there are many sources of preference heterogeneity, researchers have indicated that the underlying causes of heterogeneity need to be better understood by linking the heterogeneity to the characteristics of the decision maker (e.g. Louviere et al., 2002; Rigby and Burton, 2005; Kjær and Gyrd-Hansen, 2008; Hess, 2012).

In their seminal papers on the ICLV model framework, Ben-Akiva and colleagues (1999; 2002; 2012) suggest taking more account of process (steps involved in decision making) and context (factors affecting the process) to enhance the behavioural representation in choice models. They do so by including social-psychological constructs in choice models (Hess, 2012).

In the ICLV model framework, attitudes are used most frequently for modelling preference heterogeneity (Hess and Beharry-Borg, 2012; O'Neill et al., 2014; Mariel et al., 2015), but personality traits (Vredin Johansson et al., 2006; Yangui et al., 2016) and specific perceptions (Márquez et al., 2014; Kassahun et al., 2016) are also used. Studies have also considered the effect of the social environment on decision making (Abou-Zeid and Ben-Akiva, 2011; Kamargianni et al., 2014; Kim et al., 2014; Czajkowski et al., 2017).

We capture process and context by three latent constructs: attitude, the injunctive norm and the descriptive norm in relation to participation in a bluetongue vaccination scheme. These constructs are operationalized using latent constructs from the reasoned action approach (RAA) decision model from social psychology (Fishbein and Ajzen, 2010). This model not only suggests which constructs explain behaviour but also provides a method to measure them consistently. Sok et al. (2015, 2016b) previously applied the RAA model to the bluetongue vaccination problem. They found that attitude and social pressures (both perceived norms) best explained intention, while control considerations played only a minor role. Based on these results, only attitude, injunctive norm and descriptive norm were measured in the current survey.

Attitude is defined as “a latent disposition or tendency to respond with some degree of favourableness or unfavourableness to a psychological object”, where the latter includes behaviour (Fishbein and Ajzen, 2010, p. 76). It is the farmer's positive or negative evaluation of performing vaccination, and can be based on instrumental (e.g. risk insurance) as well as experiential beliefs (e.g. animal suffering) (Sok et al., 2015; Sok et al., 2016a). Injunctive norms are defined as “perceptions concerning what should or ought to be done with respect to performing a given behaviour”, while descriptive norms refer to “perceptions that others are or are not performing the behaviour in question” (Fishbein and Ajzen, 2010, p. 131). Sok et al. (2015) identified the following referents of influence for the bluetongue vaccination problem: family members, the veterinarian, peers and leaders, and the buyer (Sok et al., 2015).

The next section presents our materials and methods, including the choice experiment design, the indicator variables and the econometric models we use to estimate the relationships. Section 4 presents our results, while section 5 provides some discussion of the results and section 6 concludes.

6.3 Materials and methods

6.3.1 Survey

The choice experiment survey[7] measured three groups of variables: choices, indicators for the social-psychological constructs and socio-demographic characteristics. Respondents were asked to choose their preferred alternative from each of eight choice sets. Each choice set consisted of two hypothetical vaccination schemes and a no-choice option. Each vaccination scheme was defined in terms of a combination of levels for five choice attributes. Figure 1 shows an example of a choice card. Table 1 provides an overview of all attribute levels. The survey continued with statements that measured attitude and perceived norms and ended with questions about farm and farmer characteristics.

6.3.1.1 Choice experiment design

The Netherlands is currently free of bluetongue. A hypothetical scenario was therefore developed that described, as realistically as possible, a situation where bluetongue had been detected 100 kilometres from the premises of the respondent. Next, it was mentioned that veterinary experts estimated the probability of infection as 5 out of 10 farms during the summer of 2015. Animal health authorities were preparing a vaccination scheme in which the respondent could participate during the spring of 2015 (when the survey was sent out). Participation in the vaccination scheme would reduce the probability of infection at the farm towards nil. Instructions explaining the choice task followed the scenario description. Attributes and their levels were explained and an example of a choice card was shown.

The scenario description and selection of choice attributes and their levels (see Table 1) were set by a multidisciplinary team, consisting of a veterinary epidemiologist, economists specialized in animal health and a statistician, to ensure that the choice card designed to capture farmers' perceptions and preferences would be both actionable for policy makers and fit within a workable experimental design. The results from previous studies on the identification and assessment of key factors that influence decision making on bluetongue vaccination were also considered (Elbers et al., 2010; Sok et al., 2015; Sok et al., 2016a).

[7] The questionnaire is available from the authors upon request.

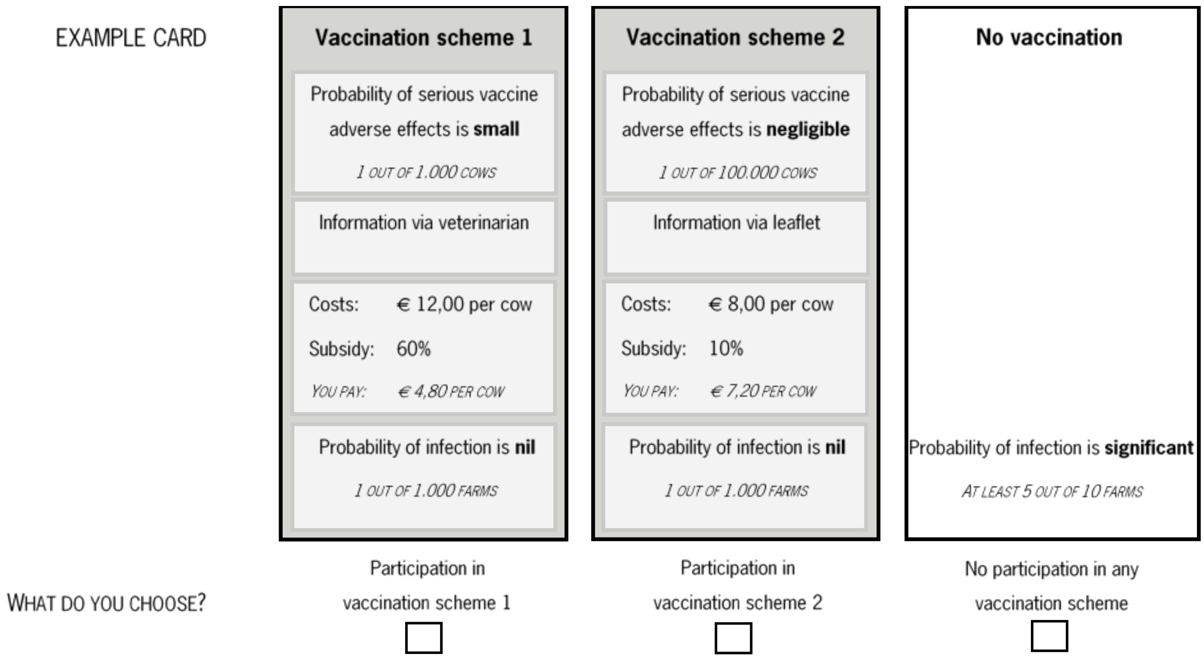

Figure 6-1: Example of a choice card with two hypothetical vaccination schemes and a no-choice alternative.

Table 6-1: Details of the selected choice attributes and attribute levels of the vaccination schemes.

	Choice attributes 1.	2.	3.	4.	5.
Description	Probability of serious vaccine adverse effects	Government communication	Government subsidy	Costs of vaccination per cow in euros	Probability of infection in the herd
Levels	Significant	No communication	No subsidiy	4	Significant (ASC_no)
	Small	*Through leaflet*	*10 per cent*	*8*	Nil (ASC_yes)
	Negligible	Through vet	60 per cent	12	
		Through lflt & vet			

Note: The base levels are in cursive text

The choice attributes 1 to 4 are policy related. The previous bluetongue vaccination scheme in the Netherlands (in 2008 – 2010) used inactivated vaccines, which have very low probabilities of adverse effects. The attribute ‘probability of serious adverse vaccine effects’ was still included to reflect farmers’ perceived trust and confidence in the vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities. Two types of policy instruments were included as attributes: ‘government information’ (communication), as an informational instrument that can increase the motivation by reasoned opinions: and ‘government subsidy’, as an incentive-based instrument to encourage participation by lowering the net cost of vaccination. The level of subsidy can also have a signalling function, indicating the extent to which the government takes the issue seriously. The attribute ‘vaccination costs per cow’ was included as a price attribute. The attribute ‘probability of infection in the herd’” only varied between the vaccination and no-vaccination (no-choice) alternatives.

A fractional factorial main-effects experimental design resulted in 16 hypothetical vaccination schemes, from which 16 choice sets were generated by means of a cyclic design. Sixteen more choice sets were generated by permuting ‘communication’ levels in such a way that all possible pairs of ‘communication’ levels appeared in choice sets. The 32 choice sets were partitioned into four blocks. Each respondent was offered eight choice cards with three alternatives: two hypothetical vaccination schemes with varying levels on the first four attributes and an opt-out alternative, the latter representing the choice not to vaccinate.

6.3.1.2 Indicators representing social-psychological constructs

Attitudes towards participation in a bluetongue vaccination scheme were measured using five 7-point semantic differential scales with bipolar adjectives, such as (un)satisfying and (un)important, taking into account both instrumental and experiential (non-use) aspects (see Table 3 below). Thus, the question for each scale was: “Participation in a vaccination scheme against bluetongue is <*adjective*> for my farm”.

Injunctive norm with respect to participation in a bluetongue vaccination scheme was measured using three 7-point Likert-type scales with end points “disagree strongly” and “agree strongly”. The three statements were: “People who have a lot to do with my farm expect me to participate in a vaccinate scheme against bluetongue”, “People whose opinions or vision I value would approve of me participating in a vaccination scheme against bluetongue” and “People who are close to me expect me to participate in a vaccination scheme against bluetongue”. Descriptive norm with respect to participation in a bluetongue vaccination scheme was measured using two 7-point Likert-type scales with end points “disagree strongly” and “agree strongly”. The statements were: “Surrounding dairy farmers will participate in a vaccination scheme against bluetongue” and “Dairy farmers in my social network will participate in a vaccination scheme against bluetongue”.

6.3.1.3 Farm and farmer characteristics

Farm characteristics were selected to capture the variation in scale and intensity with which the farm is operated, namely herd size, average milk production and the amount of pasture land utilized. Whether heifers are kept for export was the final farm characteristic measured. The farmer characteristics measured were age and level of education.

6.3.2 Econometric approach

Figure 2 visualizes the ICLV model for the bluetongue vaccination problem as an integration of a discrete choice model and a latent variable model. The use of latent variables instead of observed variables for conceptualizing social-psychological constructs is advocated by e.g. Walker (2001). The latent variable model is supposed to capture some process and context of decision making by measuring farmers' attitude and injunctive and descriptive norms. These social-psychological constructs are expected to retrieve part of the behavioural heterogeneity farmers have for different vaccination scheme attributes.

Various statistical approaches have been used to capture constructs in choice models (Walker, 2001). One approach is to include the indicators directly in the utility function (e.g. Onozaka et al., 2011). Measurement error can be introduced with this approach since the indicators are only a function of the construct and not the underlying construct itself. There is also a risk of creating endogeneity bias since it is likely that unobserved effects at the same time influence the response to choice as well as indicator questions (Ashok et al., 2002). Another approach is to first perform a factor analysis on the indicators, and then include the resulting construct(s) in the utility function (e.g. Greiner, 2015). In the aforementioned study no farm and farm characteristics were used to explain preference heterogeneity. Within the ICLV model framework, it is recognized that farm and farmer characteristics can impact both on latent variables as well as on utility (see Figure 2). Two statistical approaches result in consistent estimates for ICLV models: the sequential estimation approach (limited information, two steps) and the simultaneous estimation approach (full information, one step) (Walker, 2001).

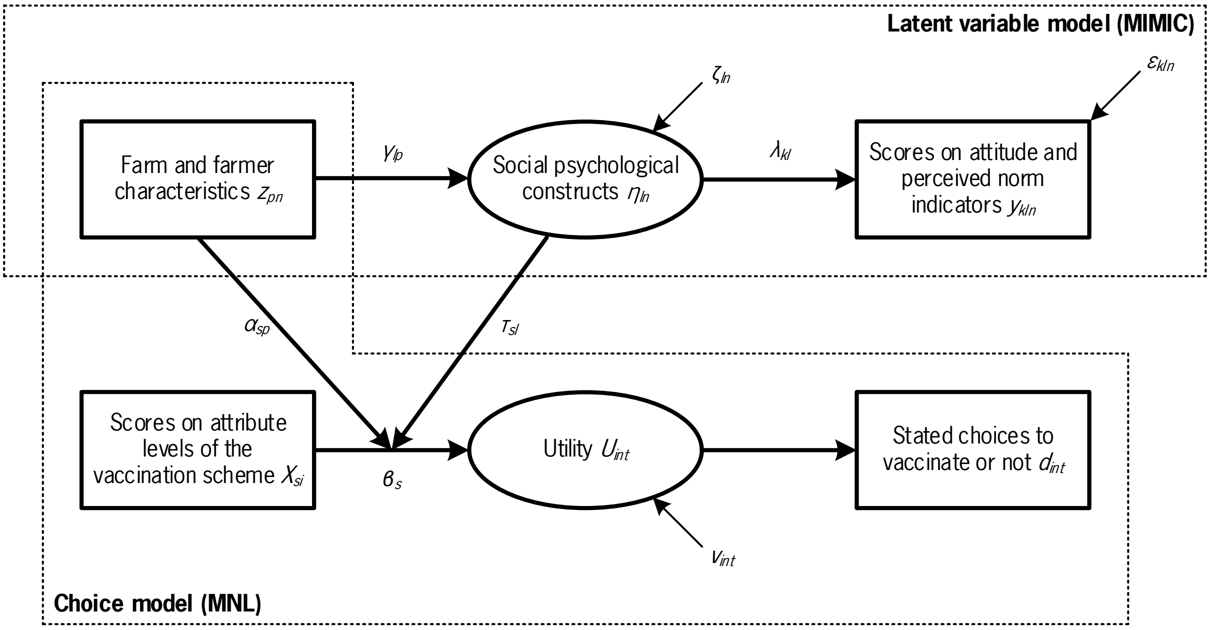

Figure 6-2: The Integrated Choice and Latent Variable model specification used in this paper where squares represent observed variables and ellipses latent variables.

In the sequential estimation approach, a multiple indicator and multiple causes model (MIMIC) (Jöreskog and Goldberger, 1975; Diamantopoulos et al., 2008) is used to specify and test the relationships between farm and farmer characteristics and the attitude and perceived norm indicators (see Figure 2). A MIMIC model is a special case of structural equation modelling (SEM). The predicted conditional means (factor scores) of these constructs are saved and entered into the choice model specification. The simultaneous estimation approach estimates a MIMIC and choice model in a single step and is thus more efficient. However, the maximum likelihood procedure often suffers from convergence problems when multiple latent variables are included because of multiple integrals (e.g. Raveau et al., 2010; Bahamonde-Birke et al., 2015; Daziano and Rizzi, 2015). We therefore adopt the consistent but less efficient sequential estimation approach[8]. The models were estimated with Stata 13 (StataCorp, 2013), which provides built-in commands for estimating SEM and alternative-specific conditional logit (McFadden's choice) models. The user-written command developed by Hole (2007) was used to estimate mixed logit models.

[8] Efforts were made to estimate the ICLV model simultaneously using Pythonbiogeme (Bierlaire, 2016) to test whether more efficient parameter estimates could be obtained. This was unsuccessful. Models with only one latent variable were successfully estimated but indicated only small differences in standard errors compared to similar models estimated in a sequential manner.

6.3.2.1 Latent variable model

The MIMIC model was estimated using the two-step approach for SEM following Anderson and Gerbing (1988). The first stage consists of testing the measurement model that specifies the relations between the latent constructs (attitude, injunctive norm and descriptive norm) and their observed indicators, also known as a confirmatory factor analysis model.

Scores on indicators y_{kln} for latent variable l were modelled as effects of scores on their corresponding latent variables η_{ln}:

$$y_{kln} = \lambda_{kl} \cdot \eta_{ln} + \varepsilon_{kln}, \tag{1}$$

where y_{kln} is the score for decision maker n on the kth reflective indicator of latent variable η_l, ε_{kln} is the measurement error in that score and λ_{kl} are factor loadings, capturing the effect of η_l on y_{kl} (Figure 2). The measurement errors for each indicator were assumed to be normally i.i.d. and uncorrelated across indicators.

The overall model fit was assessed using the goodness-of-fit measures most commonly used in the SEM literature, along with their cut-off values for acceptance (see e.g. Hu and Bentler, 1998; Hu and Bentler, 1999; Bagozzi and Yi, 2012): the root mean square error of approximation (RMSEA) ≤ 0.06, the Bentler comparative fit index (CFI) ≥ 0.95 and the standardized root mean square residual (SRMR) ≤ 0.08. The validity of the hypothesized latent constructs was also assessed[9]. Hair et al. (2010) describe construct validity as the extent to which a set of observed variables actually reflects the latent construct which those variables are designed to measure, requiring convergent and discriminant validity. Good convergent validity (reliability) of a specific latent construct is indicated by a high proportion of shared variance among indicators, and is usually assessed with the average variance extracted (AVE) and composite reliability (CR) statistics (Fornell and Larcker, 1981). Good discriminant validity means that a latent construct is truly distinct from other latent constructs, and is assessed by checking whether the AVE values of a latent construct exceed its correlations with other latent constructs.

[9] Although the simultaneous estimation approach has become standard in the ICLV literature, a potential danger when using this approach is that not enough attention is given to the validity of the hypothesized social-psychological constructs.

Given a good fit and acceptable validity, the structural model was estimated in the second stage. In addition to equation 1, the social-psychological constructs were modelled as being partially caused by observed farm and farmer characteristics (Figure 2):

$$\eta_{ln} = \sum_p \gamma_{lp} \cdot z_{pn} + \zeta_{ln}, \tag{2}$$

where γ_{lp} are regression coefficients capturing the effect of the pth farm or farmer characteristic z_p on η_l. The error terms ζ_{ln} were assumed to be normally i.i.d. and allowed to correlate across latent variables. Assuming that the farm and farmer characteristics are specified as error free, the error terms represent the impact of all remaining explanatory variables on the latent variables (Diamantopoulos, 2006). Equations 1 and 2 were jointly estimated as a MIMIC model. All farm and farmer characteristics were included simultaneously in the structural model to test their effects on the latent constructs. Effects that were not significant at the 20% critical level were removed one at a time in an iterative process, starting with the effect that had the lowest t-value (Diamantopoulos and Winklhofer, 2001). Scores for the latent variables included in the ICLV models were derived from the final MIMIC model.

6.3.2.2 Choice model

Assuming a rational cognitive process of utility maximization, the decision maker n chooses alternative i in choice situation t in which he or she faces the set of available alternatives C_{nt} if:

$$U_{int} > U_{jnt};\ \forall j \neq i, j \in C_{nt}. \qquad (3)$$

Utility U_{int} of alternative i for decision maker n in choice situation t was modelled as:

$$U_{int} = V_{in} + v_{int}, \qquad (4)$$

where V_{in} is called the representative utility, which is the part of the utility that is deterministic and v_{int} is a stochastic error term that is independently Type-1 extreme-value distributed, which leads to a multinomial (MNL) model specification (McFadden, 1974).

In the case where no preference heterogeneity is considered among decision makers, the representative utility is dependent on the trade-offs made between attributes, and V_{in} is modelled as a linear specification:

$$V_{in} = \beta_s \cdot X_{si}, \qquad (MNL) \qquad (5)$$

where X_{si} are the attributes with level s of bluetongue vaccination scheme alternative i and β_s are the regression coefficients that can be interpreted as marginal utilities. Preference heterogeneity among decision makers can be introduced in the model by adding a normally distributed stochastic component to the marginal utilities, which leads to a mixed logit (MXL) model specification (Hensher and Greene, 2003):

$$V_{in} = (\beta_s + \sigma_{sn}) \cdot X_{si}, \qquad (MXL) \qquad (6)$$

where σ_{sn} is a vector of parameters that represents the individual decision maker's deviations from the average marginal utilities, so that each decision maker now derives specific marginal utilities ($\beta_{sn} = \beta_s + \sigma_{sn}$) from the attributes. These individual deviations are assumed to be normally distributed with zero mean. Regarding the relaxation of the Independence of Irrelevant Alternatives (IIA) property in this study, correlations across alternatives and choice situations were still assumed to be zero. Preference heterogeneity can also be introduced deterministically, modelling it as a function of farm and farmer characteristics z_{pn} as well as social-psychological constructs (latent variables) η_{ln}:

$$V_{in} = \beta_s \cdot X_{si} + \left(\textstyle\sum_p \alpha_{sp} \cdot z_{pn} + \sum_l \tau_{sl} \cdot \eta_{ln}\right) \cdot X_{si}. \qquad (MNL\ with\ interactions) \qquad (7)$$

Considering five choice attributes with a total of 12 levels (Table 1), six farm and farmer characteristics and three latent constructs (Table 2), 108 interaction effects could be considered for inclusion in the model. To keep the model parsimonious, an interaction variable selection procedure[10] was executed. The most important reason for this procedure was the expected high intercorrelations between latent constructs. High intercorrelations between attitudes and perceived norms are the rule rather than the exception (Fishbein and Ajzen, 2010), and therefore the risk of multicollinearity exists if all interactions with all latent constructs are retained. Leaving latent constructs out, on the other hand, can result in omitted variable bias. Finally, an overall MNL and an overall MXL model were estimated, including all selected interaction effects.

The categorical choice attributes 1 – 3 were dummy coded, taking the levels in italics in Table 1 as base levels. Dummy coding was used to ensure an appropriate specification of the random components in the MXL models (see Walker et al., 2007). The base level for the cost attribute was located at €8. The fifth choice attribute was also dummy coded, with the value 1 for the opt-out alternative, thereby accepting a significant probability of infection in the herd. This shows the relative utility (equivalent to an alternative-specific constant (ASC)) farmers attach to the no vaccination alternative compared to the base vaccination scheme. The base vaccination scheme was represented by the following attribute levels: 'probability of serious adverse vaccine effects' is *small*, 'government communication' *though leaflet*, 'government subsidy' at *10 per cent* and the 'costs of vaccination per cow' at *€8*.

6.3.3 Sample

The sample consisted of 1,500 randomly selected Dutch dairy farms drawn from the National Cattle Identification and Registration Database. The farms selected for a previous survey on bluetongue conducted in 2014 were first removed from this database before the sample was drawn (see e.g. Sok et al., 2015). The selected farms were randomly subdivided into four groups. All of these groups received two different blocks in an ascending or descending order of choice cards. Each farmer in the sample was sent a paper copy of the survey along with an accompanying letter and a pre-paid return envelope. Farmers were offered two possibilities to fill in the

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[10] Interactions were tested one at a time by adding each interaction (involving all dummies coded for the particular attribute) separately to equation 5. This extensive procedure was done to avoid the issue that some effects would already be masked at this stage due to multicollinearity among the observed and latent variables. The criterion used was a likelihood-ratio test between a restricted (choice attributes only) and unrestricted (interactions added) model. Using this criterion, 28 of the 108 possible interaction variables were selected.

questionnaire, using the paper copy or via a web page. By filling in their e-mail address, respondents had a 10 per cent chance of winning a gift coupon worth €25.

The survey was sent out in the last week of April 2015. A reminder was sent three weeks after the survey was sent out, followed by another reminder three weeks later. A total of 280 farmers responded, a response rate of almost 19 per cent. This was low compared to the response rate of almost 28 per cent for the survey on bluetongue vaccination conducted in 2014 (e.g. Sok et al., 2015). The difference in response rates is most likely because of the timing of the surveys. The first survey was held in January/February while the second was held in April/May, when farmers are more likely to be busy with field activities.

Observations with missing values were excluded from the statistical analysis, resulting in an effective sample size of 211 respondents. Most of the excluded surveys missed the whole set of indicators or farm and farmer characteristics, or both. For surveys that missed only a few values, the most frequently missing variables were average milk production and education level (46 responses were missing both variables).

Table 2 presents descriptive statistics of the stated choices, perceived experiences during the previous bluetongue epidemic, and the scores for farm and farmer characteristics and indicators for attitude and perceived norm. The first row shows the distribution of respondents' vaccination choices. The next two rows show the perceived experiences during the previous bluetongue epidemic. The majority of the farmers always chose a vaccination alternative (64 per cent) while about one tenth never chose a vaccination alternative. Farmers who perceived their herd to be infected or perceived they vaccinated during the previous epidemic more often chose a vaccination alternative from the eight choice cards. Approximately 44 per cent of the farmers reported that they had vaccinated in the previous epidemic, indicating that the sample also captured farmers without previous vaccination experience. The sample representativeness was further checked by comparing the values for farm and farmer characteristics with the values measured by other sources. According to the Dutch Farm Accountancy Data Network, the average dairy farm in the Netherlands had 103 dairy cows and 55 hectares of land in 2015 (LEI, 2016). According to statistics from the Cattle Improvement Co-operative, average milk production (305 days) of dairy cows in the Netherlands was 8,573 kilograms in 2015 (CRV, 2015). A similar survey among dairy farmers executed in 2014 (Sok et al., 2016a) reported similar results for farmer characteristics (age and education level).

Table 6-2: Descriptive statistics of stated choices, perceived experiences of the previous bluetongue epidemic, and scores for farm and farmer characteristics and indicators of attitude and perceived norm.

Variable	Unit	Farmers who chose out of 8 choice cards			Total or average
		Always no	Sometimes yes	Always yes	
Farm(er)s	Number	20	56	135	211
Share of sample	Percentage	9.5	26.5	64.0	100.0
Past bluetongue epidemic experiences					
Infected[a]	Percentage 'yes'	30.0	39.3	48.1	44.1
	Percentage 'no'	45.0	46.4	40.7	42.7
	Percentage 'don't know'	20.0	14.3	11.1	12.8
Vaccinated[a]	Percentage 'yes'	5.0	37.5	52.6	44.1
	Percentage 'no'	85.0	58.9	43.7	51.7
	Percentage 'don't know'	5.2	3.6	3.7	3.8
Farm and farmer characteristics					
Herd size[b]	Number	105	119	97	104
Milk production [b]	Kilograms (avg. cow)	7,582	8,655	8,616	8,529
Pasture land[b]	Hectares	68	49	44	47
Export of heifers	Yes = 1, No = 0	0.10	0.18	0.32	0.26
Age[b]	Years	52	46	48	48
Higher education	Yes = 1, No = 0	0.27	0.20	0.29	0.27
Average score on indicators					
Attitude[c]	Scale 1 – 7	3.32	4.29	4.72	4.47
Injunctive norm[c]	Scale 1 – 7	2.43	3.34	4.21	3.81
Descriptive norm[c]	Scale 1 – 7	2.60	3.22	4.12	3.74

[a] One of the twenty farmers in the group 'Always no' left the questions open for past bluetongue experiences.
[b] These variables were mean-centred, before entering the choice model.
[c] These variables were factorized and normalized, before entering the choice model (see latent variable model).

6.4 Results

6.4.1 Latent variable model

In the first step, the measurement model was tested to assess the overall model fit and the validity of the latent constructs (equation 1). Values of the indices measuring the overall model fit were all below the criteria for acceptance (□2/df = 1.42 with p-value 0.06, RMSEA = 0.04, CFI = 0.99 and SRMR = 0.03). The values of the AVE (0.69, 0.56 and 0.72 for attitude, injunctive norm and descriptive norm, respectively) and CR (0.80, 0.78 and 0.84) statistics further confirmed good validity of the hypothesized latent constructs. Therefore the proposed measurement model specification was accepted and the structural model was estimated. The final MIMIC model with the selected farm and farmer characteristics showed good model fit (□2/df = 1.33 with p-value 0.03, RMSEA = 0.04, CFI = 0.98 and SRMR = 0.04).

Table 3 shows the results of this estimation. Herd size, milk production level and pasture land availability are associated with variability in attitude. These associations suggest that farmers who have more intensive dairy farms are more favourable towards vaccination. Some of these associations also apply to variability in perceived norms. Another clear pattern is that farmers who export heifers have a more positive attitude and higher injunctive and descriptive norms. Finally, older farmers scored lower on descriptive norm.

Farm and farmer characteristics explained only a little of the variance in each latent construct. Much of the unexplained variance, captured by the disturbance terms, is shared between latent constructs, as shown by the disturbance term correlations (Table 3).

Table 6-3: Estimation results from the MIMIC model.

	Attitude	Injunctive norm	Descriptive norm
	Coef. Std. Err.	Coef. Std. err.	Coef. Std. err.
Structural model			
Herd size	0.11 (0.08)	0.18 (0.08)**	
Milk production	0.08 (0.06)		
Pasture land	-0.36 (0.08)***	-0.34 (0.09)***	-0.18 (0.07)***
Export of heifers	0.19 (0.07)***	0.18 (0.07)***	0.23 (0.07)***
Age			-0.11 (0.06)*
Explained variance (R^2)	*0.14*	*0.10*	*0.10*
Measurement model			
Unsatisfying-satisfying scale	0.78 (0.03)***		
Unimportant-important scale	0.86 (0.02)***		
Bad-good scale	0.89 (0.02)***		
Useful-useless scale	-0.83 (0.02)***		
Disturbing-reassuring scale	0.79 (0.03)***		
People who have to do a lot with my farm […]		0.79 (0.04)***	
People whose opinions or vision I value […]		0.54 (0.06)***	
People who are close to me […]		0.87 (0.03)***	
Surrounding dairy farmers […]			0.80 (0.04)***
Dairy farmers in my social network […]			0.89 (0.04)***
Disturbance term intercorrelations			
Attitude	1		
Injunctive norm	0.59 (0.06)***	1	
Descriptive norm	0.58 (0.06)***	0.64 (0.06)***	1

Note: *, ** and *** indicate significance level at 0.10, 0.05 and 0.01 respectively.

6.4.2 Choice model results

Table 4 reports the final model estimations after the selection procedure for the interaction variables. All models fitted the data well: the McFadden's pseudo R^2 measures were within the range for a good model fit (0.2 – 0.4) (Hensher et al., 2005). The MXL models outperformed the MNL models, reflected in the values for the pseudo R^2, Akaike information criteria (AIC) and the Bayesian information criteria (BIC)[11].

Starting with the MNL and MXL models without interactions, positive marginal utilities imply an increase in utility relative to the base level, making participation in a vaccination scheme more probable. All marginal utilities had the expected sign, e.g. the marginal utility of vaccination costs was negative, meaning that higher cost decreases utility and the likelihood of participation in a vaccination scheme. Compared to the vaccination scheme with base levels, the likelihood of participation increased with the probability of serious adverse vaccine effects being negligible, government communication provided via veterinarians and government subsidy of 60 per cent. The likelihood of participation decreased with vaccination costs and the probability of serious adverse vaccine effects being significant. The utility of no government subsidy was not significantly different from the base level of 10 per cent, suggesting that the level of subsidy has a categorical rather than a marginal effect on preferences. Something similar held for government communication: the utility of no communication was not significantly different from the base level of providing information through leaflets. Finally, the significant negative beta of the no-choice or opt-out alternative indicated that if farmers did not choose any vaccination alternative, their utility significantly reduced. This suggests that many farmers are willing to participate in a bluetongue vaccination scheme to minimize the probability of infection in their herd.

The estimated sigma's in the MXL model show the choice attributes that have preference heterogeneity. This was the case for all choice attributes except government communication. In the MNL and MXL models with interactions, most interaction effects related to the probability of infection in the herd (ASC) and the probability of serious adverse vaccine effects.

[11] Both mixed models were also estimated without any identification constraints on the standard deviations of the random marginal utility coefficients. Results showed that our identification constraints (fixing the standard deviations of the marginal utilities for the base levels to 0), closely (for the model without interactions) or perfectly (for the model with interactions) coincided with the recommendation by Walker et al. (2007) to constrain the smallest standard deviations from the unconstrained models to 0 for identification.

Table 6-4: Estimation results from the choice models after selection of the interaction variables.

		MNL	*MNL with interactions*	*MXL*[b]		*MXL with interactions*[b]	
Main effects		β	β	β	σ	β	σ
Adverse effects prob. *(base: small)*	Significant	-1.77 (0.10)***	-1.78 (0.12)***	-6.68 (0.98)***	5.37 (0.81)***	-6.48 (1.03)***	4.64 (0.67)***
	Negligible	0.41 (0.09)***	0.50 (0.11)***	1.69 (0.32)***	2.39 (0.44)***	1.69 (0.37)***	2.62 (0.56)***
Government comm. *(base: through leaflet)*	No communication	0.16 (0.12)	0.09 (0.13)	0.03 (0.28)	0.31 (0.59)	-0.14 (0.29)	0.35 (0.59)
	Through vet	0.30 (0.12)**	0.25 (0.13)**	0.72 (0.27)***	0.03 (0.59)	0.65 (0.29)**	0.71 (0.46)
	Through lflt & vet	0.13 (0.11)	0.09 (0.12)	0.10 (0.26)	0.02 (0.49)	0.06 (0.27)	0.13 (0.56)
Government subsidy *(base: 10 per cent)*	No subsidy	-0.09 (0.08)	-0.10 (0.09)	-0.18 (0.20)	1.17 (0.37)***	-0.12 (0.21)	1.10 (0.41)***
	60 per cent	0.83 (0.11)***	0.91 (0.12)***	2.51 (0.39)***	1.45 (0.41)***	2.74 (0.44)***	1.46 (0.45)***
Vaccination costs		-0.14 (0.01)***	-0.16 (0.02)***	-0.54 (0.08)***	0.33 (0.06)***	-0.58 (0.09)***	0.31 (0.07)***
Infection probability	ASC_no	-0.62 (0.11)***	-0.83 (0.15)***	-4.96 (0.99)***	9.29 (1.61)***	-3.80 (0.97)***	6.95 (1.09)***
Interaction effects			α or τ			α or τ	
Herd size[a]	× ASC_no		0.06 (0.02)***			0.21 (0.11)*	
Milk production[b]	× ASC_no		-0.27 (0.07)***			-0.85 (0.55)	
Pasture land[a]	× Significant		-0.19 (0.06)***			-0.55 (0.23)**	
	× Negligible		0.05 (0.03)			0.20 (0.12)*	
	× ASC_no		-0.01 (0.04)			0.02 (0.24)	
Export of heifers	× ASC_no		-0.56 (0.21)***			-2.33 (1.80)	
Age[a]	× No subsidy		-0.16 (0.09)*			-0.42 (0.21)**	
	× 60 per cent		-0.34 (0.11)***			-0.90 (0.30)***	
	× Vaccination costs		0.02 (0.01)*			0.10 (0.05)**	
	× ASC_no		-0.11 (0.09)			-0.90 (0.65)	
Education	× Significant		-0.56 (0.23)**			-1.43 (1.01)	
	× Negligible		0.06 (0.22)			0.48 (0.64)	
Attitude	× No communication		0.08 (0.14)			0.61 (0.36)*	
	× Through vet		0.30 (0.15)**			0.87 (0.37)**	
	× Through lflt & vet		-0.14 (0.14)			-0.19 (0.31)	
	× ASC_no		-0.93 (0.15)***			-3.03 (1.06)***	
Injunctive norm	× No subsidy		-0.07 (0.10)			-0.32 (0.23)	
	× 60 per cent		-0.21 (0.12)*			-0.69 (0.32)**	
	× ASC_no		-0.51 (0.14)***			-2.02 (1.05)*	
Descriptive norm	× Significant		-0.12 (0.11)			-0.53 (0.50)	
	× Negligible		0.18 (0.11)*			0.73 (0.31)**	
	× ASC_no		-0.19 (0.13)			-0.87 (0.99)	
Model fit statistics							
Parameters		9	32	18		41	
L0 (with ASC only)		-1771	-1771	-1407		-1407	
LL		-1395	-1134	-842		-774	
McFadden pseudo-R^2		0.21	0.36	0.40		0.45	
AIC/N		1.67	1.39	1.02		0.97	
BIC/N		1.71	1.51	1.09		1.13	

Note: $N_{choice\ cards}$ = 1680, $N_{respondents}$ = 211. Std. deviation in parentheses. *, ** and *** indicate significance level at 0.10, 0.05 and 0.01 respectively.

[a],[b] All observations were divided by 10 and 1000 respectively, for scaling reasons.

[c] The simulated maximum likelihood was based on 5,000 Halton draws (Hole, 2007).

Results from the MIMIC model previously suggested that higher scores on the latent constructs are relatively weakly associated with larger-scale farms, more intensive farms and farms that keep heifers for export. Part of these effects are thus absorbed in the predicted conditional means of these latent constructs. However, the underlying farm characteristics still interacted significantly with some choice attributes, in particular with the marginal utility of the no-vaccination option. Thus, farmers operating larger-scale and/or more intensive dairy farms are more likely to vaccinate, as are farmers who export heifers.

Farmers' age and education level were not influential in the MIMIC model in explaining variability in the latent constructs. In the choice models with interactions, age had a moderating effect on monetary attributes: the level of government subsidy and vaccination costs. Older farmers appear willing to pay more for the vaccine given that they derive less utility from the government subsidy of 60 per cent and less disutility from higher vaccination costs. Farmers with higher education degrees are less likely to vaccinate if the probability of serious adverse vaccine effects is significant[12].

Attitude and injunctive norm interacted negatively with the ASC – the utility of the no-choice or opt-out alternative. Thus, the more favourable the farmer's attitude towards vaccination and the more social pressure perceived by the farmer, the more likely the farmer is to vaccinate. Attitude also interacted positively with government communication provided via veterinarians, while injunctive norm interacted negatively with government subsidy of 60 per cent. Descriptive norm interacted positively with the probability of serious adverse vaccine effects being negligible.

[12] An interaction effect between education level and the ASC was highly significant in both the MNL and MXL models. However, the interaction variable selection procedure revealed that this correlation was spurious. Since dummy coding was used, the effect captured was the significant interaction between education level and the probability of serious adverse vaccine effects being small (see Bech and Gyrd-Hansen (2005) for an explanation).

6.5 Summary and discussion

In their utility trade-offs between choice attributes, farmers perceived the probability of serious adverse vaccine effects as one of the most important attributes. Preference heterogeneity for this attribute was retrieved via interactions with pasture land, education level and descriptive norm. The first two interaction effects might show that farmers' views on disease resistance (or resilience) and its consequences for the intensity with which a farm should be operated are linked with how they perceive the likelihood and impact of adverse vaccine effects. This links to results from the latent variable model, where it was found that farmers who have more (less) intensive dairy farms are more (less) favourable towards vaccination.

The importance of perceived trust and confidence in vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities is highlighted by two interaction effects in particular. Descriptive norm interacted positively with the probability of serious adverse vaccine effects being negligible. This suggests that farmers are more likely to vaccinate if they perceive that others in their social network vaccinate (presumably without experiencing adverse effects). Furthermore, attitude interacted positively with government communication provided via veterinarians. Attitude change, communication and persuasion are closely related. Source and message characteristics (e.g. credibility) together with the internal motivation and ability to process information determine whether attitude change is induced (e.g. Petty and Cacioppo, 1996; Blackstock et al., 2010). Sok et al. (2015) previously showed for the same research problem that the government representative was one of the least important referents, while the veterinarian and peer farmers were more important referents. Frewer et al. (1996) show that for food-related risks, government representatives are among the least trusted sources of risk information.

Another important finding relates to the provision of a government subsidy as a means to lower the vaccination costs for the farmer. Injunctive norm interacted negatively with government subsidy of 60 per cent. Subsidization is an incentive-based policy instrument and functions, just as certain norms, as an external motivating factor. As such, subsidization and social pressures via injunctive norms are both external motivating factors. Our results indicate that these factors might function as substitutes for at least some farmers.

This 'crowding out' effect has been reviewed by Bowles and Polanía-Reyes (2012, p. 368), who indicate that "this may occur when incentives adversely affect individuals' altruism, ethical norms, intrinsic motives to serve the public, and other social preferences". One of the suggested underlying mechanisms for the substitution effect is that subsidies can negatively affect one's sense of autonomy (and not the capacity) over the behaviour, resulting in resistance to rather than compliance with the policy.

The interactions found between farm characteristics and the ASC reveal some clear economic motives for farmers to prefer vaccination to no vaccination. Herd vaccination is often used as an insurance against the production risk from disease infection, and also guarantees that heifers can be continuously exported irrespective of the status of the epidemic (Sok et al., 2014). However, the interactions found between social-psychological constructs and the ASC suggest that perceived social pressures also induce vaccination behaviour as well as the experiential components of attitude (e.g. animal welfare considerations). This suggests that in addition to economic motives, farmers can have social and intrinsic motives to invest in disease control.

This study brings together different perspectives from economics and social psychology[13] using the flexible structure of the ICLV model framework. Compared to the MNL, the social-psychological constructs explain a considerable part of the preference heterogeneity in the ASC, resulting in better model fit statistics. Compared to the MXL model with preference heterogeneity modelled randomly, the social-psychological constructs retrieve some preference heterogeneity and provide behavioural explanations for the diverse preferences underlying farmers' choices to vaccinate against bluetongue. In particular farmers' attitude provided a sound behavioural interpretation of why vaccination is preferred to no vaccination. Attitude has also been used to explain status quo effects in choice experiments (Meyerhoff and Liebe, 2009). Other latent constructs that could be relevant for modelling preference heterogeneity in livestock disease control decisions are anticipated emotions, such as guilt or regret (Onwezen et al., 2013), or dimensions of personal norms (Thøgersen, 2006). In this respect, choice models are emerging that are based on minimizing anticipated random regret rather than on maximizing random utility (Thiene et al., 2012; Hensher et al., 2013; Chorus, 2015).

[13] Some of the axioms underlying the standard economic model could have been violated with the inclusion of social-psychological constructs, for a discussion see Ben-Akiva et al. (1999).

6.6 Conclusions and policy implications

Results of this study suggest that, in the presence of a bluetongue outbreak, many dairy farmers in the Netherlands are willing to participate in a vaccination scheme to minimise the probability of herd infection. Farmers have economic, intrinsic or social motives to invest in livestock disease control. The likelihood of participation can be increased with providing information and subsidies, however, the efficacy of these policy instruments to motivate farmers to vaccinate is heterogeneous and not necessarily positive for each farmer. This study has two implications for the design of policy instruments to increase the effectiveness of voluntary approaches to livestock disease control.

The first policy implication relates to the provision of subsidies. In designing livestock disease control schemes, it is often argued that governments should use financial, incentive-based policy instruments to compensate farmers for externalities, assuming they act in rational self-interest. The results of this study suggest that farmers can have private economic motives (incentives) to participate in a vaccination scheme, such as to insure the production risk from disease infection and to maintain the export of heifers. This suggests that a government subsidy might not be necessary for each farmer to guarantee a positive net benefit from vaccination. Results further suggest that the relationship between the level of subsidy and the likelihood of participation in voluntary vaccination schemes is not necessarily positive. A crowding-out effect was found between injunctive norm and government subsidy. The crowding out of intrinsic and social motives could be minimised by explaining to farmers what the meaning is of providing subsidy and where the financial sources come from. The level of subsidy and the manner in which compensation and reimbursement is offered can have a signalling function, indicating the extent to which the animal health authorities take the issue seriously.

The second implication relates to the provision of information. Perceived trust and confidence in the vaccine safety and effectiveness and in the government approach, which were reflected in preferences for the attributes 'probability of serious adverse vaccine effects' and 'government communication', were conditional on farmers' attitude and descriptive norm towards participation in a vaccination scheme. Information about the vaccine and the way in which animal health authorities plan to coordinate the vaccination strategy is best provided via communication channels that are perceived as credible and trustworthy. Farmers are more likely to vaccinate if they perceive that others in their social network perform vaccination without experiencing adverse effects.

Chapter 7

Farmers' motives, voluntary vaccination schemes and disease spread: an agent-based model for bluetongue

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Abstract

Voluntary livestock disease control is an interplay between the dynamics of farmers' collective behaviour and disease epidemiology. This study used an agent-based model to study this interplay for bluetongue disease. Farmers' utility function was derived from the results of a discrete choice model in which economic, intrinsic and social motives to vaccinate were considered. The epidemiology was modelled by a stochastic spatial explicit susceptible-latent-infectious-recovered model. Under specific vaccination scheme designs, an emergent effect evolves from the interactions between farmers themselves and with the environment from which they observe the progress of the disease. These schemes focus more on serving farmers' information needs and raising perceived trust and confidence in the vaccine and in the disease control approach chosen by animal health authorities.

Keywords

Livestock disease control, policy instruments, voluntary approach, agent-based model, transmission kernel, integrated choice and latent variable model, information diffusion

7.1 Introduction

The EU has set specific legislation for a number of livestock diseases, describing what control measures each member state should adopt in case an outbreak is observed. One of such livestock diseases is bluetongue (BT), which is a vector-borne disease caused by the bluetongue virus (BTV). A large epidemic of BTV serotype 8 occurred in Europe during 2006 to 2009. After the august 2006 outbreak it was commonly assumed that the epidemic would be halted by the 2006/2007 winter period. The epidemic did, however, spread quickly over a vast area in 2007 (Elbers et al., 2009a). The adoption of the recommended measures (European Council, 2000; European Council, 2007) did not control the spread. New legislation was developed in which it was proposed to apply a mass emergency vaccination campaign "to achieve the objectives of reducing clinical disease and losses, containing the spread of the disease, protecting free territories in the Member States and facilitating safe trade in live animals" (European Council, 2008). The Dutch animal health authorities used a voluntary vaccination approach and two types of policy instruments to motivate participation. A communicative intervention was implemented in which the government representatives as well as farmer organizations conveyed written or oral recommendations to the farmers to vaccinate their cattle. Subsidization of the vaccination costs was another policy instrument put in place (Ministry of Economic Affairs, 2008).

Voluntary livestock disease control is an interplay between the dynamics of farmers' collective behaviour and disease epidemiology. Principal-agent theory suggests that livestock disease control can be seen as a contractual relationship between the (national) animal health authorities and a group of farmers (Hennessy and Wolf, 2015). While the animal health authorities' prime interest is to control the disease transmission as efficiently as possible given the European and international responsibilities, the farmers want to avoid a disruption of the business and consequently high economic damage. By investing in disease control measures, such as vaccination, the probability of being infected itself is reduced. It also creates positive off-farm effects since the farm in its vaccinated state is not likely to infect other susceptible farms. If enough farmers would vaccinate, this could even lead to so-called herd-immunity (Topley and Wilson, 1923), such that the epidemic is halted completely. No disease control efforts, on the other hand, increase the probability of being infected itself and create negative off-farm effects. It is therefore important to understand and explicit account for this interplay between disease dynamics and farmers' behavioural dynamics in models that are used to provide underpinnings for livestock disease control policies.

As different authors in the field of economics of animal health have noticed (Rich and Perry, 2011; Barnes et al., 2015; Gilbert and Rushton, 2016), a body of economic literature that studied the effects of the abovementioned dynamic interplay used stylised economic models, mostly without epidemiological input, based on mainly information economics approaches, principal-agent theory and game theory to describe farmers' behaviour (Hennessy et al., 2005; Gramig et al., 2009; Horan et al., 2015; Wang and Hennessy, 2015). The models used are limited in their ability to account for process and context in decision making, while future conditions depend heavily on actions of other farmers (Nolan et al., 2009). They assume all farmers can only be extrinsically motivated via (monetary) incentives. Intrinsic or social motives to invest in livestock disease control are assumed not to play a role or remain constant. Given the expected information asymmetry in disease status and control efforts of others, the emphasis is on setting the right level of financial compensation to create the right incentives to invest in voluntary livestock disease control.

This study uses a bottom-up approach by means of an agent-based model (ABM) to study the dynamic interplay between farmers' collective behaviour and disease epidemiology. ABM is a computational method, and its advantage lies in the possibilities to model individual behaviour, connect farmers (agents) with each other through a social network, and situate them in an environment that accounts for spatial and temporal effects (Gilbert, 2008; Nolan et al., 2009; Rich and Perry, 2011; Chhatwal and He, 2015).

A variety of decision models has been applied in ABM to represent agent's behaviour, ranging from rational choice theories, to social-psychological and cognitive theories to just empirical or heuristic rules with or without any theoretical foundation (An, 2012; Klabunde and Willekens, 2016; Groeneveld et al., 2017). Here, farmers' behaviour in the ABM is modelled using the integrated choice and latent variable model (ICLV) framework. The ICLV model offers a general econometric framework to supplement economic theory with concepts or theories from other social sciences (Walker and Ben-Akiva, 2002; Ben-Akiva et al., 2012). Such models are seen as a promising way to model individual behaviour in ABM (Bruch and Atwell, 2015; Klabunde and Willekens, 2016). The ICLV model framework was applied to empirical data from a survey-based discrete choice experiment in which farmers' preferences for BT vaccination scheme attributes were elicited (Sok et al., 2017).

The main results from the study of Sok et al. (2017) can be summarised as follows. There is heterogeneity in farmers' motives to invest in livestock disease control. Economic motives (incentives) relate to insuring the production risk from infection and maintaining the export of heifers. Farmers can have social and intrinsic motives to invest. They consider what important referents, such as the veterinarian or family members, think they should do and taken into account the perceived behaviour of peers. They do not want to be confronted with animal suffering but want to keep job satisfaction high from working with healthy animals. This suggests that a mix of policy instruments, rather than financial compensation only, is needed to make voluntary approaches effective (Barnes et al., 2015; Ochieng' and Hobbs, 2016). Interaction effects found between social-psychological constructs and specific designs of policy instruments highlighted the importance of perceived trust and confidence in the vaccine safety and effectiveness and in the disease control strategy chosen by animal health authorities. For example, some farmers were more likely to vaccinate if they perceive that others in their social network perform vaccination without experiencing adverse effects. Some farmers were less likely to vaccinate with a higher level of government subsidy. This pointed to a crowding-out mechanism (Frey and Jegen, 2001) in which subsidization adversely affect farmer's motivation to comply with the vaccination policy.

The objective of this study was to analyse farmers' willingness to invest in BT disease control under different voluntary vaccination scheme designs, considering economic, social and intrinsic motives and the dynamic interplay between farmers' collective behaviour and disease epidemiology. The past BT epidemic of 2006 – 2009 served as a case study. The epidemiology of BT is modelled by a stochastic spatial explicit susceptible-latent-infectious-recovered (SLIR) model, in which the probability of transmission from an infectious farm to a susceptible farm is a function of interfarm distance and the infectious period (Boender et al., 2007; de Koeijer et al., 2011).

The remainder of this paper is organised as follows. Section 2 provides a model outline, the verification steps, and other details. Section 3 reports on simulations in which different vaccination scheme designs were tested on disease rate and vaccination uptake level. Section 4 and 5 are the discussion and conclusion.

7.2 Materials and methods

7.2.1 Agent-based model outline

The agent-based model (ABM) was programmed in Netlogo 5.3 (Wilensky, 1999). A two-dimensional geographical space $A \times B$ in km^2 is formed, and the total number of farms N. Each farm is placed in the two-dimensional space at a random position. One vector season (Spring to Autumn) is simulated and denoted with a time period T (in days) in which the epidemic starts with an initial number of infectious farms.

All farms are subjected to the decisions of one farmer, and each farmer only makes decisions for one farm. Farmers in the model observe and collect information about the closeness and number of infected farms, and about vaccination behaviour of others in their social network. Figure 1 shows the dynamic interplay between farmers collective behaviour and the BT disease epidemiology. Section 2.1.1 and subsections describe in more detail how farmers use this information to decide whether they should participate in a BT vaccination scheme offered by the animal health authorities. Section 2.1.2 describes how the BT transmission is modelled.

Section 2.2 describes the verification and validation steps done. Section 2.3 describes a sensitivity analysis done on some input parameters relating to the social network and transmission. Section 2.4 describes the vaccination scheme designs tested on the percentage of farms infected or vaccinated over time.

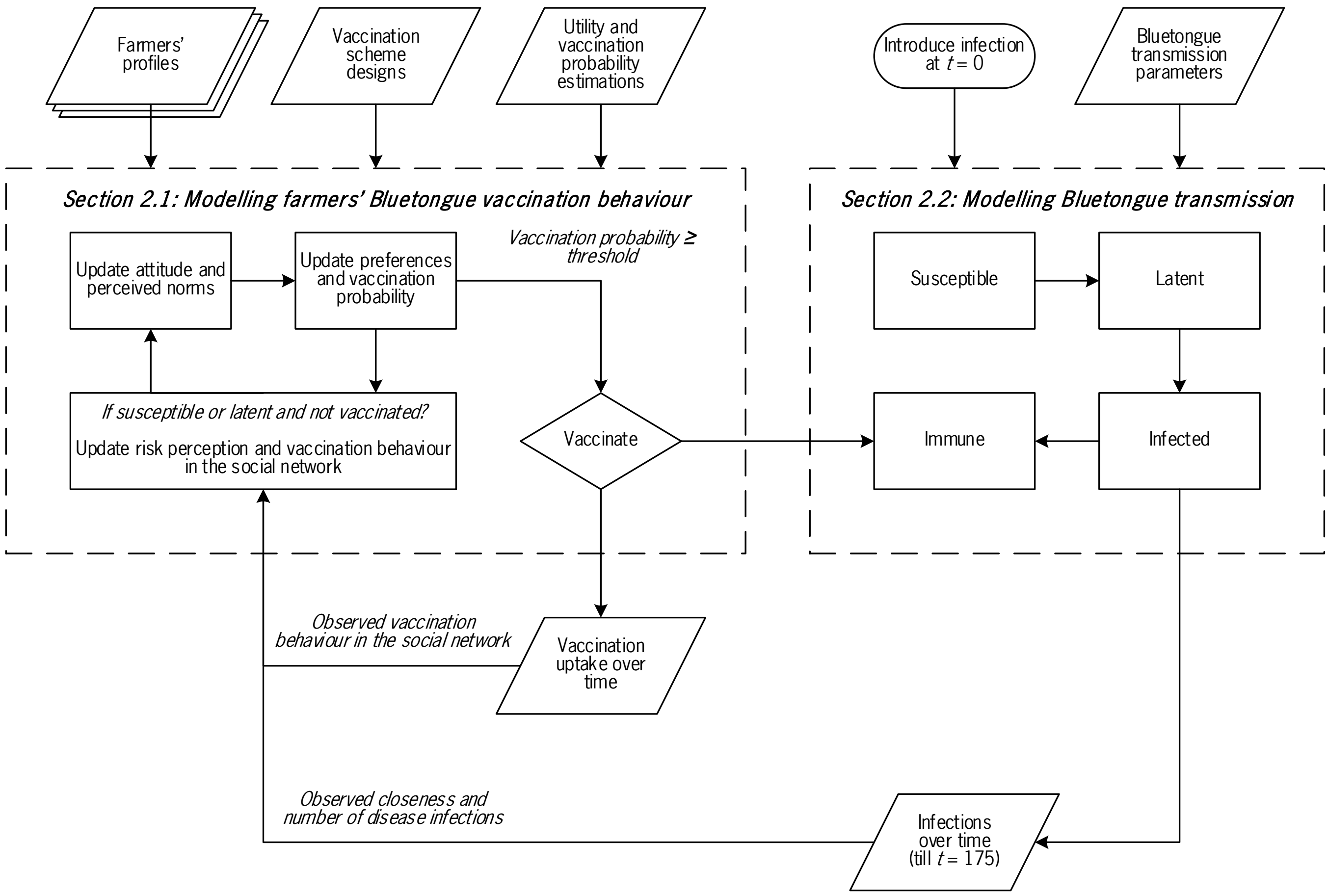


Figure 7-1: Overview of the information flow between and within sub models of farmers' vaccination behaviour and disease epidemiology.

7.2.1.1 Modelling farmers' bluetongue vaccination behaviour

7.2.1.1.1 Choice model framework

The vaccination decision is essentially formulated as a discrete choice problem, which is consistent with random utility and other econometric models (Lancaster, 1966; McFadden, 1974). Farmers in the ABM are offered a vaccination scheme. The utility derived from that vaccination scheme is the sum of utility derived from the attributes of that vaccination scheme. Five attributes of a BT vaccination scheme were identified (Table 1).

Table 7-1: Attributes of a bluetongue vaccination scheme (Sok et al., 2017).

Attribute (X)	Levels (s)	Description
Adverse effects probability	Significant Small Negligible	Farmers' perceived trust and confidence in the vaccine safety and effectiveness and in the disease control approach chosen by animal health authorities
Government communication	No information Via leaflet Via veterinarian Via leaflet and veterinarian	Informational policy instrument that can increase the motivation to vaccinate by reasoned opinions
Government subsidy	No subsidy 10 per cent 60 per cent	Incentive-based policy instrument that can increase the motivation to vaccinate by lowering the net costs
Vaccination costs per cow	4 Euro 8 Euro 12 Euro	Farmers' contribution to the costs of herd vaccination (excluding financial compensation)
Infection probability	Significant Nil	If farmers' choose to vaccinate, the probability of herd infection becomes nil

The ICLV model is an extended discrete choice model, in which the random utility model is generalised (Walker and Ben-Akiva, 2002). Social-psychological constructs are modelled as latent variables to account for heterogeneity in preferences to enhance the behavioural representation in choice models. The latent constructs that were used in the study of Sok et al. (2017) to explain preference heterogeneity were attitude, injunctive norm and descriptive norm. These constructs from the reasoned action approach successfully explained farmers' intention to vaccinate against BT (Fishbein and Ajzen, 2010; Sok et al., 2016b).

Farmer's attitude towards BT vaccination is the positive or negative evaluation of performing it, and can be based on instrumental as well as experiential aspects (Sok et al., 2015; Sok et al., 2016a). The injunctive norm refers to the farmer's perceptions of what referents think he or she should do. Influential referents are: family members, the veterinarian, peers and leaders, and the buyer (Sok et al., 2015). The descriptive norm refers to farmer's perceived behaviour of others (peers).

7.2.1.1.2 Social network

A social network structure is imposed that connects farmers in the ABM by the idea of social circles (Hamill and Gilbert, 2015). The latter provides a simple structure that fits with sociological observations of real social networks, such as low density, high clustering and communities. In the setting of a network model using the idea of social circles, Hamill & Gilbert (2009) indicate that the distance between any pair of farmers (r_{nm}) is seen as the strength of the tie between them, the social dimension of distance. Since the geographical dimension of distance is essential in this ABM, it is assumed that geographical distance alone determines social relationships.

Specifically, a two-reach network model is applied (Hamill and Gilbert, 2009). The total number of farms N is randomly split into two groups, a major (N_{major}) and a minor (N_{minor}), the first with a small radius (R_{small}), the second with a larger radius (R_{large}). Farmers in N are connected if $r_{nm} \leq R_{small}$ (peer connections). Farmers within N_{minor} are in addition connected if $R_{small} < r_{nm} \leq R_{large}$. This approach results in a so-called fat-tailed distribution of connectivity, i.e. some farmers have large networks. The latter group has in addition to peer connections, contacts with farmers from e.g. a study or pressure group or board.

7.2.1.1.3 Farmer profiles

In total, 211 complete dairy farmer profiles were obtained with data on stated choices to different vaccination scheme designs (five attributes with one selected level), indicators for social-psychological constructs and farm and farmer characteristics (see Sok et al., 2017). Each farmer agent in the ABM was attributed with one of these farmer profiles. The descriptive statistics of these farmer profiles are shown in Table 2.

Table 7-2: Descriptive statistics of farmer profiles from Sok et al. 2017.

Variable	Unit	Mean	Standard deviation
Farm characteristics			
Herd size[b]	Number	104	48
Milk production[b]	Kilograms (avg. cow)	8,529	1,118
Pasture land[b]	Hectares	47	33
Export of heifers	Yes = 1, No = 0	0.26	
Farmer characteristics			
Age[b]	Years	48	10
Higher education	Yes = 1, No = 0	0.27	
Social-psychological constructs			
Attitude[a,b]	Scale 1 – 7	4.71	1.32
Injunctive norm[a,b]	Scale 1 – 7	3.81	1.44
Descriptive norm[a,b]	Scale 1 – 7	3.74	1.33

[a] These variables were factorized, see Sok et al. (2017)
[b] These variables were scaled to a value between 0 and 1

A multinomial model specification from the related econometric study of Sok et al. (2017) was used to assign each farmer profile with an initial vaccination probability for different vaccination scheme designs that are composed of the same five attributes (Table 1) but with different levels (Table 4):

$$Pr_{in} = \frac{1}{1+exp(-V_{in})}, \tag{1}$$

where $V_{in} = \beta_s \cdot X_{si} + \left(\sum_p \alpha_{sp} \cdot z_{pn} + \sum_l \tau_{sl} \cdot \eta_{ln}\right) \cdot X_{si}, \quad (2)$

Pr_{in} is the vaccination probability and V_{in} the utility derived from vaccination scheme design i for decision maker n,

X_{si} five attributes with selected level s;

β_s estimated main effects that can be interpreted as marginal utilities;

z_{pn} value of farm and farmer characteristic p in a farmer profile;

α_{sp} estimated interaction effects between z_{pn} and X_{si};

η_{ln} score on social-psychological construct l in a farmer profile;

τ_{sl} estimated interaction effect between η_{ln} and X_{si}.

The estimated effects are given in Appendix I. Given the variety in scores on social-psychological constructs and values for farm and farmer characteristics, each farmer profile (Table 2) has a different total utility score, that leads to a different initial vaccination probability. When this probability exceeds a given threshold the farmer decides to vaccinate his farm (see Figure 1).

7.2.1.1.4 Updating vaccination probabilities

The vaccination decision problem is short-term and therefore all farm and farmer characteristics will not change and are of no influence in the decision-making process. Attitude, injunctive and descriptive norm however, are belief-based and formed in daily encounters in the real world (Fishbein and Ajzen, 2010). These constructs are used in the decision-making process to update the vaccination probabilities (Figure 1). Two simple heuristics update the attitude, injunctive norm and descriptive norm using temporal and spatial information available from the ABM.

Each farmer observes and collects the number and closeness of BT infected farms and construes a risk perception (RP) as follows:

$$RP_{nt} = \left(\frac{I_t}{N}\right)^{\frac{min(r_{nm})}{r_{max}}}, \tag{3}$$

where I_t the number of N infected farms at time t, r_{nm} the inter-farm distance between a farm n and infected farm m and r_{max} the maximum possible distance between two farms in the simulation. Farmers' attitude (η_A) is during the simulation updated as:

$$\eta_{A,nt} = \eta_{A_0,n} \times (1 + RP_{nt}), \tag{4}$$

where $\eta_{A_0,n}$ is the initial attitude score, being normalised score with a value between 0 and 1. Note that the effect of risk perception on the updated attitude score is multiplicative through the initial attitude score, i.e. the effect of risk perception will be proportional to the initial attitude score.

For each connection between farmer n and farmer neighbour m in the social network the similarity (SIM_{nm}) is calculated by taking the inverse Euclidean distance of the differences in herd size, milk production, land and farmer's age. Each farmer observes the number of vaccinated network links (NWL_{nmt}) and perceives social pressure (SP) to vaccinate as a function of the number of neighbour farmers who already vaccinated:

$$SP_{nt} = \left(\frac{\sum_m NWL_{nmt} \times SIM_{nm}}{\sum_m SIM_{nm}}\right)^{NWS}. \tag{5}$$

Note that neighbour farms with higher similarity contribute more to perceived social pressure. The network size sensitivity (NWS) parameter in the power term is a value between 0 and 1. A value < 1 results in giving more weight to the first neighbour farmer who vaccinated, especially in smaller social networks.

Farmers' descriptive norm (η_{DN}) is updated during the simulation as:

$$\eta_{DN,nt} = \eta_{DN_0,n} \times (1 + SP_{nt}), \tag{6}$$

where $\eta_{DN_0,n}$ is the initial descriptive norm score, being normalised score with a value between 0 and 1. Note that the effect of perceived social pressure on the updated descriptive norm score is multiplicative through the initial descriptive norm score, i.e. the effect of perceived social pressure will be proportional to the initial descriptive norm score.

Farmers' injunctive norm (η_{IN}) is during the simulation updated as:

$$\eta_{IN,nt} = \eta_{IN_0,n} \times (1 + RP_{nt} \times w_A + SP_{nt} \times w_{DN}), \tag{7}$$

where $\eta_{IN_0,n}$ is the initial injunctive norm score, being normalised score with a value between 0 and 1. Farmers' injunctive norm is updated by a weighted average of the updated attitude and descriptive norm scores ($w_A + w_{DN} = 1$). Note that the effect of the risk perception and the perceived social pressure on the updated injunctive norm score is multiplicative through the initial injunctive norm score, i.e. the effect of perceived social pressure will be proportional to the initial injunctive norm score.

7.2.1.2 Modelling bluetongue transmission

The epidemiology of BTV is modelled by a stochastic spatial explicit SLIR model. A farm, which is subject to one farmer n, is in one of four possible states; susceptible (S), latent infected (L), infectious (I), or recovered (R). BT is introduced at time moment t_0 at a number of randomly selected farms. Farms transit from the S to the L state during transmission of the BTV. The farms will be latently infected for a constant latent period T_{lat} during which transmission cannot occur. During the infectious period with a constant length T_{inf}, farms can infect other farms. After the constant infectious period the infectious farm recovers and goes into the R state. Farms in the R state cannot be reinfected.

Transmission is modelled stochastically by a Poisson process in which an infectious farm infects susceptible farm at distance r_{nm} with rate $\lambda(r_{nm})$ (Law and Kelton, 2000). A susceptible farm is infected at the earliest infection moment for all infectious farms. The rate at which the virus is transmitted is modelled as:

$$\lambda(r_{nm}) = \frac{\lambda_0}{1+\left(\frac{r_{nm}}{r_0}\right)^{\alpha}} \tag{8}$$

where λ_0 is the rate of transmission at distance 0, r_0 a scaling distance and α determines the shape of the kernel. Small values of α represent global transmission and high values depict transmission kernels with primarily local spread (Boender et al., 2007; de Koeijer et al., 2011).

Vaccination of farms will render susceptible farms protected against infection. Vaccination of infected farms in the L state will not affect the status of these farms. Farms in the I state cannot be vaccinated.

7.2.2 Verification and validation

Verification and validation steps were run before the effectiveness of different vaccination scheme designs is tested. Verification is defined by Gilbert Gilbert (2008) as: "the task of ensuring that a model satisfies the specification of what it is intended to do". Specific verification steps done were the checking of the Netlogo numerical code by both authors, diagnosing intermediate outputs (e.g. the updating of the social-psychological constructs), observing the simulation one at a time, and corner testing with extreme values (e.g. setting the infectious period at zero, which should lead to no additional infected farms).

Validation is defined by Gilbert (2008) as "checking that the model is a good model of the phenomenon being simulated". Two output variables were defined (see also Figure 1): (1) the percentage of infected farms during the simulation and (2) the percentage of vaccinated (immune) farms during the simulation. All input parameters were set at their default value (see Table 3). First, 50 simulations were run in which no vaccination scheme was offered. Then, 50 simulations were run with the base vaccination scheme design offered at t = 56 (approx. after 2 months) to the farmers in the model (see Table 4). The simulation is calibrated to reflect the percentage of infected and vaccinated farms in Velthuis et al. (2010), Elbers et al. (2010) and Sok et al. (2016a).

7.2.3 Sensitivity analysis: testing input parameters

The parameters relating to the social network and transmission were subject to a sensitivity analysis to study the effect on the two output variables defined. The sensitivity of each parameter value was analysed over a range of values while keeping all other parameters fixed to the default value. For each parameter value, 50 simulations were run and output is shown at the end of the time period, at $t = 175$. Parameters for describing farmer behaviour that were obtained from empirical data in the discrete choice experiment survey and the econometric analysis were not varied. Table 3 presents the input parameters in the ABM.

Table 7-3: Input parameters, their default values and the range of values simulated in the agent based model.

Input parameters	Symbol	Default	[Range of values] (incremental step)	Unit	Source
General					
Vector-active season (sim. period)	T	175	-	days	(Fischer et al., 2013)
Scaling distance	r_0	3.9		km	de Koeijer et al. (2011)
Social network					
Minor farm group	N_{minor}	20	[0 – 30] (10)	per cent	
Small radius	R_{small}	2	[1 – 4] (1)	km	
Large radius	R_{large}	4	[2 – 8] (2)	km	
Network size sensitivity	NWS	0.5	[0.25 – 1] (0.25)	-	
Inj. norm updating mechanism	w_A / w_{DN}	0.5	[0 – 1] (0.5)	-	
Transmission					
Initial number of infectious farms	-	6	[1 – 11] (5)	farms	
Initial transmission rate	λ_0	1500	[750 – 3000] (750)	10^{-6} day^{1}	
Latent period	T_{lat}	14	[7 – 21] (7)	days	de Koeijer et al. (2011)
Infectious period	T_{inf}	56	[28 – 84] (28)	days	Based on Gubbins et al. (2008)

Regarding the social network structure, the share of farmers in the minor group with large networks, the size of the small and large radius were varied to test if smaller or larger networks would lead to different percentages of farms infected or vaccinated. The network size sensitivity and weights used in updating the injunctive norm were also varied to test whether it would matter if either risk perception or perceived social pressure or a combination of the updating mechanisms would give different values for the outcome variables.

Regarding the BT epidemiology the parameter values in the study of de Koeijer et al. (2011) were used, but the initial transmission rate λ_0 was increased to obtain an similar sized outbreak. The sensitivity of the model was analyzed for the initial number of infectious farms, the initial transmission rate λ_0 , the length of the latent period T_{lat} and the length of the infectious period T_{inf}. The initial number of infectious farms during the 2006 outbreak is unknown and might affect the initial speed of spread of the infection. The transmission rate might change from year-to-year due to differences in vector-abundance. For the length of the latent period the same assumption as in the study of de Koeijer et al. (2011) was used, but evidence is scarce and therefore this parameter was subject to sensitivity analysis. Furthermore, De Koeijer et al. (2011) assumed that farms remain infectious until the end of the vector season. Here it is assumed that a farm is infectious only when its cattle is infected, resulting in a shorter infectious period of 56 days. This assumption was obtained by simulating a BT outbreak on a farm using the model in the study of Gubbins et al. (2008) with an average temperature of 19.5ºC and 100 cows.

7.2.4 Scenario analysis: testing different vaccination schemes

Table 4 presents five vaccination scheme designs in terms of the selected levels for the attributes (see also Table 1). The effect of the time of introduction of the intervention on the percentage of farms infected or vaccinated was considered. Each scheme was simulated for three moments of introduction: at t = 28, 56 and 84 (approx. after one, two and three months). The threshold value was set at 0.97, and calibrated in such a way that the average percentage of vaccinated farms in the base scenario is about equal to the average of the initial vaccination probability distribution of that scenario. Output is shown at the end of the time period, at t = 175.

For each design the vaccination costs per cow are kept constant at 8 Euros and the probability of herd infection when vaccinating, per definition, is nil. The vaccination schemes thus only differ from each other in selected levels for the first three attributes.

Vaccination scheme 1 is the base scenario with no distinct levels on the first three attributes. The average uptake level is estimated at 48 per cent (Sok et al., 2017), and this percentage is used to calibrate the model.

Compared to the base scenario, in vaccination scheme 2 the risk communication strategy is changed by disseminating government information via veterinarians rather than via leaflets. Serving the information needs of intrinsically motivated farmers might be enough to encourage vaccination. Veterinarians are perceived as a highly trusted information source (Sok et al., 2015). Farmers' preference for receiving information via veterinarians is positively correlated with attitude (Sok et al., 2017), and updated in the ABM via a measure of risk perception based on the number and closeness of BT infected farms (equation 3 and 4).

Table 7-4: Selected levels of attributes and expected vaccination uptake level for each of the five vaccination schemes.

	Scheme 1: Base	Scheme 2: Comm. via vets	Scheme 3: Comm. via vets, more confidence	Scheme 4: Extra subsidy	Scheme 5: Comm. via vets and extra subsidy
Vaccination scheme attributes					
Prob. of serious vaccine adverse effects	Small	-	Negligible	-	-
Government communication	Leaflet	Veterinarian	Veterinarian	-	Veterinarian
Government subsidy	10%	-	-	60%	60%
Vaccination costs per cow	8 euro	-	-	-	-
Prob. of herd infection	Nil	-	-	-	-
Initial vaccination prob. distribution (Sok et al., 2017)					
Average	0.48	0.53	0.61	0.65	0.68
Min	0.01	0.00	0.01	0.02	0.01
25^{th} percentile	0.24	0.26	0.38	0.50	0.54
Median	0.50	0.58	0.69	0.69	0.76
75^{th} percentile	0.70	0.78	0.86	0.85	0.89
Max	0.96	0.98	0.99	0.98	0.99

In vaccination scheme 3 it is assumed that a risk communication strategy via veterinarians also leads to more perceived trust and confidence in the vaccine and in the disease control strategy chosen by animal health authorities, and therefore the probability of serious vaccine adverse effects' is perceived as negligible. Farmers' preference for the latter is positively correlated with descriptive norm (Sok et al., 2017), and updated in the ABM via a measure of perceived social pressure based on the number of vaccinated network links (equation 5 and 6).

Vaccination scheme 4 is aimed at increasing farmers' motivation by providing a higher financial compensation. Farmers' preference for receiving more subsidy is negatively correlated with injunctive norm (Sok et al., 2017), and updated in the ABM via a weighted average of the perceived risk and perceived social pressure (see equation 7).

The final vaccination scheme tested has favourable levels on both the informational and incentive-based policy instrument. The average uptake level for this scheme is estimated at 68 per cent (Sok et al., 2017).

7.3 Results

The symbols depicted in the Figures 2, 3 and 4 represent the percentage of farms infected (circles) or vaccinated (crosses) at the end of the time period, at t = 175. The dashed horizontal lines in Figure 3 are the average uptake levels of the base vaccination scheme, and in Figure 4 these lines are the average uptake levels of the corresponding vaccination scheme, based on the estimations of the related econometric study of Sok et al. (2017),

7.3.1 Validation of the model

Figure 2 shows the results of two simulations with in the first graph the percentage of infected farms if no vaccination scheme is offered, and in the second and third graph the percentage of vaccinated and infected farms if the base vaccination scheme is offered. With this scheme, approximately 50 per cent of the herd on the farms in the model become immune through vaccination, and consequently the percentage of infected farms drops with approximately 50 per cent compared to the simulation in which no scheme is offered.

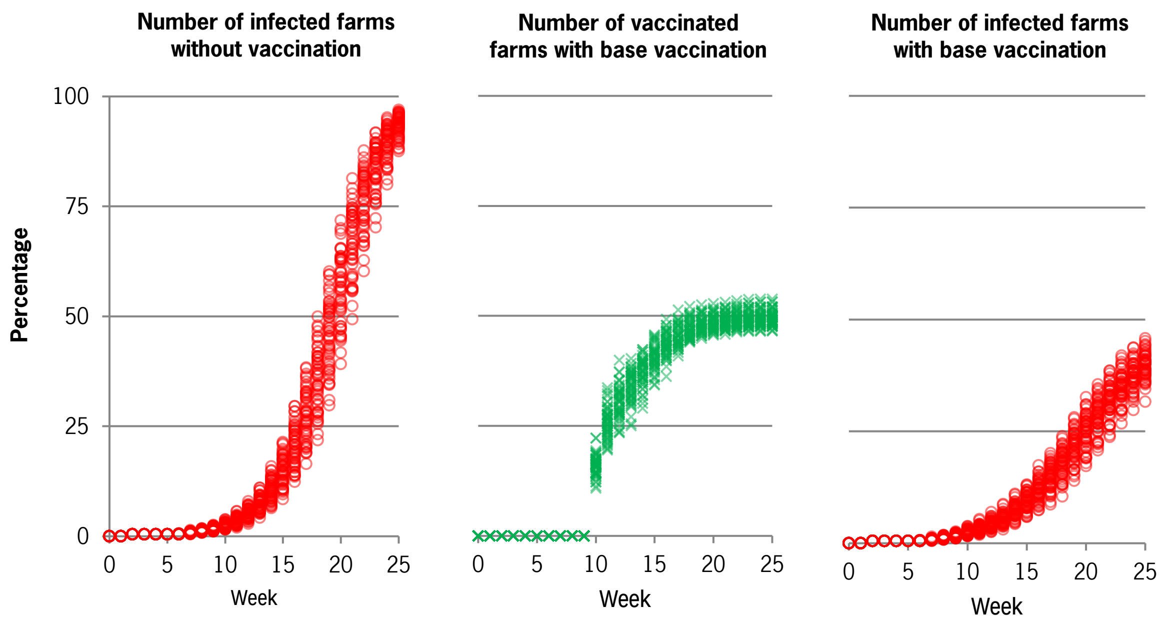


Figure 7-2: Time trajectories of simulations without vaccination and with the base vaccination scheme.

Although the simulated world differs spatially and socially from the Netherlands, a comparison of the simulations with the BT serotype 8 epidemic from 2006 – 2009 in the Netherlands shows that it has a reasonable description of the epidemiology and vaccination uptake levels. Based on data from the Animal Health Service on screening farms, Velthuis et al. (2010) estimated the percentage of BT infected farms in the Netherlands (all types) in 2006 at 2.6 per cent and in 2007 at 82.7 – 99.9 per cent, depending on the region (North, Middle or South). The percentage of infected farms in the simulated epidemics in the ABM without vaccination are in line with these percentages.

A vaccination scheme at transnational level started in Spring 2008. In the Netherlands, the vaccines and associated costs were subsidized in 2008, but in 2009 this was stopped. In a questionnaire undertaken in 2009, the level of participation among cattle farmers in 2008 was estimated at 71 per cent and at 57 per cent in 2009. The latter percentage was measured either as actual participation or a stated intention to vaccinate (Elbers et al., 2010). In a questionnaire undertaken in 2014, Sok et al. (2016a) estimated the lower limit of participation at 40 per cent of the total population of farmers. The number of farms with vaccinated herds in the ABM under the base vaccination scheme is in the range of these values.

7.3.2 Sensitivity analysis

The output variables, the percentage of infected farms and the percentage of vaccinated farms during the simulation, were hardly sensitive to the parameters relating to the social network. Results are therefore not extensively discussed in this section, but only shown graphically in Appendix II.

Figure 3 shows the simulation results in which some sensitivity of the output variables to the input parameters relating to the transmission was observed. The initial transmission rate and the infectious period are both positively correlated with the number of infected farms at the end of the simulation run. Both parameters increase the speed of transmission between farms either by a direct increase of the transmission rate or by increasing the force-of-infection, because farms remain infectious for a longer period. Increasing the latent period will reduce the speed of spread, such that less farms than the potential maximum (i.e. the final epidemic size) are infected at the end of the vector season. However, if the final epidemic size can be reached within one vector season, the final size is expected to increase with an increase in the basic reproduction number. The latter is proportional to both the initial transmission rate and the length of the infectious period, and will thus increase if these parameters are increased.

The effect of the initial number of infectious farms is two-fold. Firstly, increasing the number of initial farms will increase the initial speed of spread, such that more farms are infected during a vector-season. Secondly, a higher initial number of infectious farm will decrease the stochastic variation at the start of the vector-season, which results in less variation in the percentage of infected farms at the end of the vector season.

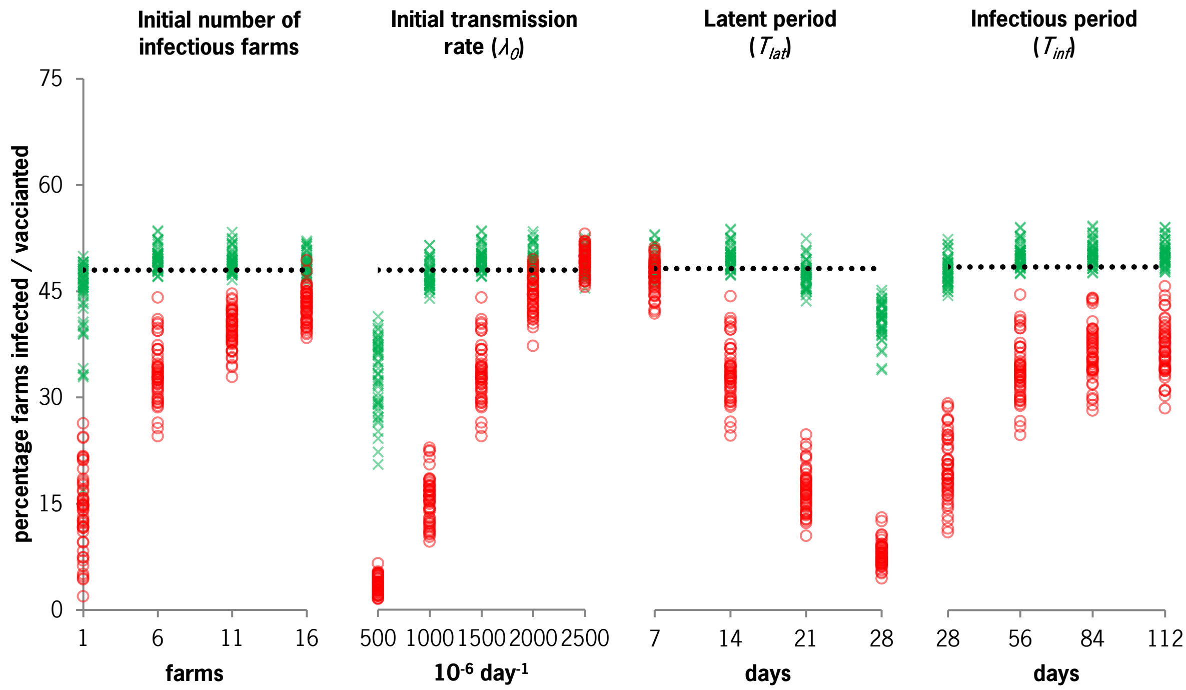


Figure 7-3: Sensitivity of the percentage infected and vaccinated farms to epidemiological parameters.

7.3.3 Scenario analysis

Figure 4 shows the simulation results of the five vaccination scheme designs described in section 2.4. The numbers for scheme 1 at t = 56 is the same result as described in Figure 2.

The relative effect of the time of vaccination introduction on the percentage of infected or vaccinated farms is about the same for all vaccination schemes. Starting vaccination at t = 28 or 56 does not lead to different vaccination uptake levels. Starting earlier can results in a somewhat lower percentage of infected farms. At t = 84, the uptake is considerably lower since farmers who might consider vaccination have already observed that their herd is infected.

Vaccination schemes 2 to 5 give an improvement over the base scheme in terms of higher percentages of vaccinated farms and lower percentages of infected farms. Schemes 2 and 3 with a focus on informing farmers using a risk communication strategy perform equally well or better than scheme 4 with a focus on incentivising farmers through financial compensation. Scheme 5 with both policy instruments actively used performs equally well as scheme 3.

A comparison of the dashed horizontal lines with the simulated uptake levels suggests that the usefulness of informational policy instruments was underestimated in the study of Sok et al. (2017) while the usefulness of incentive-based policy instrument was overestimated. This might be explained as an emergent effect (see e.g. Chhatwal and He (2015) for an explanation) that evolves under specific vaccination scheme designs from the interactions between farmers themselves and with the environment from which they observe the progress of the disease.

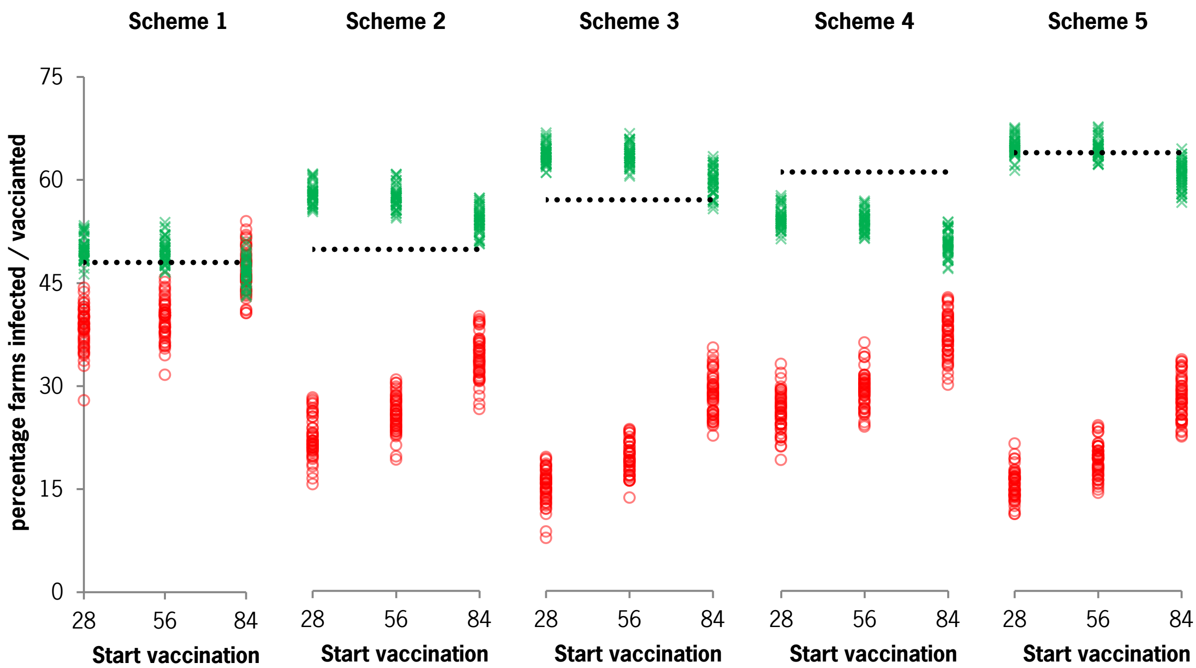


Figure 7-4: Scenario analysis of the different vaccination schemes.

7.4 Discussion

This ABM combined two widely used modelling frameworks for describing on the one hand the spread of infectious diseases and on the other hand human decision making. A susceptible-latent-infectious-recovered (SLIR) model framework was combined with an integrated choice and latent variable (ICLV) model framework, rooted in random utility and different econometric models. The social-psychological constructs attitude, injunctive norm and descriptive norm from the reasoned action approach decision model that were incorporated in the choice model provided a way to describe the process and context of decision making. The research objective was to analyse farmers' willingness to invest in BT disease control under different voluntary vaccination scheme designs, considering economic, social and intrinsic motives given an on-going epidemic.

Two discussion points arise from this modelling study. The first is about the limited absolute effect found of the epidemiological parameters on farmers' collective behaviour. The second relates to what factors make voluntary approaches to (BT) disease control more effective.

In the ABM, farmers processed the information on a daily basis by two simple heuristics: a risk perception that was construed from the number and closeness of infected farms and the perceived social pressure based on the number of vaccinated farms in the social network. Social interaction was modelled in the ABM using the two-reach network model (Hamill and Gilbert, 2009; Hamill and Gilbert, 2015). Social relationships (network links) were formed on the basis of geographical distance, while the strength of influence via the measure of perceived social pressure was fixed and based on the similarity in the farm and farmer characteristics of herd size, milk production, land and age. A minor group of farmers in addition to peer connections in the immediate neighbourhood also had contacts with farmers located further away. Information about the disease spread and vaccination behaviour of peers in the social network was readily available in the model. Both diffusion processes impact farmers' collective behaviour interchangeably (Keeling and Eames, 2005; Bauch and Galvani, 2013).

The limited effect of the BT disease transmission parameters, i.e. fast spreading or starting with a high initial number of infectious farms, on farmers' collective behaviour is explained by the difference in the speed of the information and disease diffusion processes. The BT epidemiology was modelled with a susceptible-latent-infectious-recovered model in a spatial context with many local transmissions and a small number of long-distance transmission events. The presence of this latency period results in the slower spread of disease compared to the spread of vaccination, because the diffusion of information in the social network is updated daily.

For future research using computational methods to study the dynamic interplay between farmers' collective behaviour and disease epidemiology this shows that small differences in time scale of diffusion processes will show strong responses independent of the underlying risk, i.e. local infections.

Reasoned action theory (Fishbein and Ajzen, 1975; Fishbein and Ajzen, 2010) that was used in the ABM advocates that beliefs can be established in three different ways: via direct observation, via accepting information from some outside source, or via a process of inference from some other belief. Farmers in the ABM influenced each other in a way as described by the threshold model (Granovetter, 1978), in which the threshold is the proportion of vaccinated neighbours that is necessary to convince the farmer to also vaccinate. Another possibility to model the social interaction influences and investigate more the role of opinion leaders is by the relative agreement algorithm model (Deffuant et al., 2002; Deffuant et al., 2005); Farmers can persuade their peer farmers to adopt an innovation given diverging attitudes (opinions) about the innovation and the uncertainty, conviction, and openness to the opinion of others.

It was *a priori* expected that the highest vaccination uptake level could be reached by incentivising farmers through financial compensation. The results of the ABM simulations, however, suggests that informing farmers using a well-designed risk communication strategy is at least as effective especially when there is trust and confidence in the vaccine safety and effectiveness. First, this shows that dynamic models can provide valuable insights into complex interactions between variables over time. They can capture remarkably subtle feedback effects that are easily missed by comparative static models (Nolan et al., 2009; Schreinemachers et al., 2009). Second, the results indicate that different perceptions of farmers need to be understood well before (BT) disease control strategies based on a voluntary approach can be effective. Using social interaction mechanisms, such as the perceived social pressure to vaccinate, in policy making to increase the uptake level would only work when farmers have trust and confidence in the suggested approach to control the disease.

The strength of an agent-based model is the ability to define interaction processes at the individual level in order to study population level dynamics. In this ABM study, the individual farmer level decision making process was a strong driver for the overall effects, while the social interactions between farmers was less pronounced. The interactions between farms via the transmission network was even less pronounced, due to a difference in time scale between decision making (days) and infection dynamics (weeks). Interestingly, with a low disease spread the overall effects were visible at population level, while as soon as a certain speed was reached the diffusion of information on the social network drives the dynamics.

Although targeted and risk-based vaccination strategies are more effective in controlling infectious diseases on a network (Miller and Hyman, 2007; Nian and Wang, 2010), the simulations show that a voluntary approach based on proximity is reducing the number of infected farms. Vaccination does, however, not confer herd immunity such that a proportion of susceptible farms is still infected in each scheme design tested.

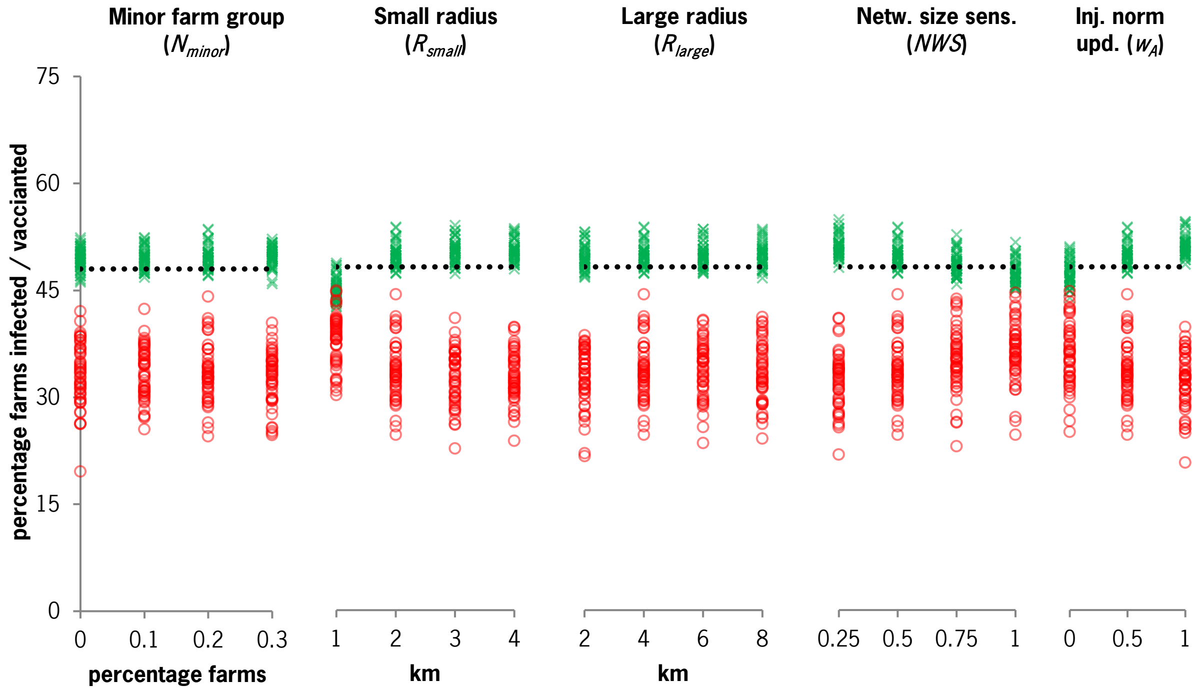
Appendix

Appendix table A7.1: Estimated effects from Sok et al. (2017), adapted for the purpose of this study.

		Original coding for meaningful interpretation[a]	Coding for ABM[b]
Main effects (β_s) of attribute X with level s			
Adverse effects probability	Significant	-1.34	-0.36
	Small	0.41	0.26
	Negligible	0.93	0.09
	No information	-0.01	-0.07
Government communication	Via leaflet	-0.11	0.07
	Via veterinarian	0.15	-0.54
	Via leaflet and veterinarian	-0.02	0.54
Government subsidy	No subsidy	-0.37	-0.44
	10 per cent	-0.27	-0.94
	60 per cent	0.64	1.38
Vaccination costs (per euro)		-0.16	-0.23
Infection probability	Significant	-0.90	3.75
Interaction effects (α_{sp}) between farm or farmer characteristic z_{pn} and attribute X with level s			
Herd size	× Significant (infection probability)	0.06	1.71
Milk production	× Significant (infection probability)	-0.28	-1.96
Pasture land	× Significant (adverse effects probability)	-0.15	-5.69
	× Small	0.04	1.70
	× Negligible	0.10	3.99
	× Significant (infection probability)	0.03	1.19
Export of heifers	× Significant (infection probability)	-0.53	-0.53
Age	× No subsidy	0.01	0.06
	× 10 per cent	0.17	1.18
	× 60 per cent	-0.18	-1.24
	× Vaccination costs (per euro)	0.02	0.16
	× Significant (infection probability)	0.10	0.71
Higher education	× Significant (adverse effects probability)	-0.49	-0.49
	× Small	0.24	0.24
	× Negligible	0.25	0.25
Interaction effects (τ_{sl}) between social-psychological construct η_{ln} and attribute X with level s			
Attitude	× No information	0.02	0.09
	× Via leaflet	-0.06	-0.28
	× Via veterinarian	0.23	1.10
	× Via leaflet and veterinarian	-0.19	-0.90
	× Significant (infection probability)	-0.97	-4.67
Injunctive norm	× No subsidy	0.02	0.10
	× 10 per cent	0.09	0.40
	× 60 per cent	-0.11	-0.49
	× Significant (infection probability)	-0.38	-1.63
Descriptive norm	× Significant (adverse effects probability)	-0.13	-0.63
	× Small	-0.02	-0.11
	× Negligible	0.15	0.73
	× Significant (infection probability)	-0.19	-0.91

[a] The reason why the reported coefficients differ from those published in Sok et al. (2017), is that effect coding instead of dummy coding was used.

[b] While the variables z_{pn} and η_{ln} used in the model estimation in Sok et al. (2017) were prepared for maximum meaningful interpretation (e.g. through mean-centering), for the ABM they were only scaled between 0 and 1 before estimation. This was done for the development of consistent heuristics (risk perception and perceived social pressure).



Appendix figure A7.1: Rank scores and some descriptive statistics of the attitudinal beliefs (b_{ij}) and outcome evaluations (e_{ij}).

Chapter 8

General discussion

8.1 Introduction

Voluntary approaches are being considered nowadays by animal health authorities as a tool for controlling livestock diseases. In 2008, the Dutch animal health authorities used a voluntary vaccination approach to control an emerging bluetongue epidemic that started end of 2006. Two types of policy instruments were used at that time to motivate participation: a communication intervention and subsidization of the vaccination costs.

The overarching research objective of this thesis was to assess the key determinants of farmers' willingness to vaccinate against bluetongue and study the impact of different policy designs on the effectiveness of voluntary vaccination approaches to bluetongue disease control.

A three-stage research approach was conducted. Two models of decision making, one from economics and one from social psychology, were first applied to the case study to obtain a solid understanding of important perceptions and motivations that farmers have for investing in livestock disease control. These motivations (sometimes incentives) and perceptions were then related to different attributes of a vaccination scheme to have a better understanding in which way a higher uptake can be obtained. In the third stage, the effect of the interplay between farmers collective behaviour and disease epidemiology on disease rate and vaccination uptake was studied.

The remainder of this chapter is organised as follows. First, a synthesis of the results of this thesis is given. Three research themes emerged from the findings: how farmers cope with risk in the context of livestock diseases, on the usefulness of financial compensation as a policy instrument, and the role of trust and social norms. The implications for policy making are subsequently discussed, followed by the main scientific contributions of this thesis, and recommendations for future research.

8.2 Synthesis of the results

Starting point in reasoning how farmers likely make decisions to invest in livestock disease control was expected utility theory (EUT) in chapter 2. With high probabilities of herd exposure and disease effects at the start of the outbreak, according to EUT, the theoretical expectation is that the farmer decides to vaccinate. Re-vaccination is uncertain during the course of the epidemic due to a lower probability of herd exposure and enduring protection against infection from previous vaccination. Factors that make re-vaccination more likely to happen are risk-averse behaviour and farm management aimed at the export of heifers, since herd vaccination allows export to continue even though the country is not free from disease.

Economic motives to invest in livestock disease control were considered only in chapter 2; intrinsic or social motives were not considered. The farmer was modelled as an economic rational decision maker, i.e. a person that acts autonomously and in its own self-interest. In chapter 3 and 4, the reasoned action approach (RAA) from social psychology was tested on a sample of dairy farmers. The relative importance of the social-psychological constructs in predicting the intention to participate in a vaccination scheme against bluetongue was assessed in chapter 3. It was found that intended vaccination behaviour is mainly explained by farmers' attitude, but also by social pressures from injunctive and descriptive norm. With respect to expected utility theory, the latter suggests that farmers do not act as autonomous actors but are influenced by what referents think what ought to be done and what the expected behaviour of other farmers will be.

The most influential beliefs underlying the social-psychological constructs were assessed in chapter 4. Results suggests that for attitude, instrumental beliefs (e.g. risk reduction) as well as experiential beliefs (e.g. animal welfare) are important drivers of the vaccination decision. This indicates that in addition to monetary outcomes of the decision, at least a group of farmers also consider the non-monetary (or non-pecuniary) outcomes. The results further showed that the most influential referents for the farmer are the veterinarian, his or her family members and colleague dairy farmers (peers).

From the findings thus far, three themes for livestock disease control will be further elaborated on. These themes coincide with shortcoming of the standard economic model of rational choice to describe and predict behaviour. The first theme is about *understanding how farmers cope with risk* in the context of livestock diseases. The standard economic model's explanation is risk aversion, which comes from the expected utility maximisation of a concave utility of wealth function. Research from the field of human judgement and decision making shows different anomalies of this view (e.g. Kahneman and Knetsch, 1991; Rabin and Thaler, 2001). The second theme focuses *on the usefulness of financial compensation as a policy instrument* given farmers' heterogeneity in motives to invest in livestock disease control. The standard economic model's view is that people have no incentives to invest in a contribution to a public good, and therefore should be compensated to maintain their private welfare and induce contribution. The third theme discusses *the role of trust and social norms*. Recognising that the market, which is a central concept in the standard economic model, is only one of the coordination mechanisms for carrying out transactions, insights from new institutional economics highlight the role of trust and social norms as a means to lower the transaction costs (Granovetter, 1985; Coleman, 1988; Williamson, 2010).

Understanding how farmers cope with risk

Chapter 2 based on EUT and the chapters 3 and 4 based on the RAA all highlight that disease risk reduction is an important motivation for investing in herd vaccination. How farmers cope with risk is a process that is determined by their risk attitude and their risk perceptions. Much of the scientific debate in agricultural decision (or risk) analysis has been on the assessment of the risk attitude (or preferences), which is reflected by the shape of the utility function. Nowadays, the proposed s-shaped utility function from cumulative prospect theory is also tested (Bocquého et al., 2013; Franken et al., 2014). Less attention is given to how farmers make judgments about probabilities and consequences of uncertain events (Lybbert and Just, 2007; Hardaker and Lien, 2010; Just et al., 2010).

In chapter 5, farm management and behavioural characteristics were explored that could explain heterogeneity in farmers' attitudinal beliefs regarding vaccination against bluetongue. Self-reported measures of risk attitude, risk perception, and the Big Five personality traits from psychology were associated with variability in these beliefs. Risk attitude and risk perception were positively related to milk production intensity and discriminated 'vaccination intenders' from non-intenders. These observations suggest that not all farmers might be risk averse with respect to production risks from livestock disease outbreaks, as is often assumed in the economic literature (Saha et al., 1994; Hardaker et al., 2015).

Production risks, however, stem from different sources, and livestock disease is one of these. Behavioural decision research emphasizes that the risk attitude can differ from domain to domain (Weber et al., 2002; Hansson and Lagerkvist, 2012; Reynaud and Couture, 2012) and highlight the importance of experiences, emotions and affect in perceptions of risk (Slovic et al., 2004; Slovic et al., 2007). Within the risk domain of livestock diseases, risk attitude and risk perception can already differ by the characteristics of the disease. For example, endemic livestock diseases might be seen as an operational risk while epidemic livestock diseases as a catastrophic risk (Valeeva et al., 2011). In the middle of an emergent (bluetongue) livestock disease epidemic, farmers' perception of risk may be higher than more objective risk estimations from veterinary experts (Zingg and Siegrist, 2012).

Conscientiousness, in addition to measures of risk, discriminated farmers in chapter 5 into 'vaccination intenders' and non-intenders. High scores in conscientiousness are typically associated with risk aversion (Nicholson et al., 2005). It remained somewhat unclear how conscientiousness relates to livestock disease control, as it can be a sense of duty, achievement striving or both (Moon et al., 2012). The feasibility and necessary conditions for combining personality psychology and economic theory are investigated (Borghans et al., 2008; Cobb-Clark and Schurer, 2012).

On the usefulness of financial compensation as a policy instrument

Results of the chapters 2 to 4 indicate that farmers' willingness to invest in livestock disease control is driven by economic, intrinsic and social motives. This is partly explained by personal differences in perceived risk and personality traits. In chapter 6, a survey-based discrete choice experiment was used to study more deeply farmers' choices for different voluntary bluetongue vaccination scheme designs. A generalised random utility model of farmers' behaviour allowed for heterogeneity in motives to invest in livestock disease control. Findings from chapter 6 empirically confirmed theoretical expectations from chapter 2 which stated that farmers can have private economic motives (incentives) to participate in a vaccination scheme, such as to insure the production risk from disease infection and to maintain the export of heifers. For farmers who see the economic benefits of vaccination, providing subsidies as a means to create net monetary benefits is redundant. A commonly held view among economists about the role of subsidization to incentivise behaviour is that governments should use it when farmers do not see a private benefit from vaccination, e.g. due to lower perceived risk or negative net benefit, while there is still a need to increase the vaccination uptake for the sake of the whole (e.g. Bennett, 2012).

This line of reasoning was worked-out in chapter 2, and it was recommended to adjust the provision of financial compensation to the farmers' willingness to vaccinate over time. In the light of the results of all other chapters, this recommendation is not complete. It is important to account for the fact that voluntary behaviour can be motivated intrinsically, extrinsically, or both. Subsidization is an incentive-based policy instrument and functions, just as certain norms, as an external motivating factor. In chapter 3 and 4, it was shown that farmers' willingness to vaccinate against bluetongue is partially driven by perceptions what ought to be done, called injunctive norms. Among the most influential referents were the veterinarian, family members and peers, while government representatives were one of the least influential referents.

A key result from the choice experiment in chapter 6 was the finding that subsidization adversely affected farmer's motivation to comply with the vaccination policy. One of the vaccination scheme attributes defined in the choice experiment was the level of government subsidy (none, 10 per cent or 60 per cent). It was found that providing more subsidy interacted negatively with the strength of injunctive norm. Explanations in the economic literature exist and can be linked to motivation crowding theory (e.g. Frey and Oberholzer-Gee, 1997; Frey and Jegen, 2001; Gneezy et al., 2011; Bowles and Polanía-Reyes, 2012). Results of this thesis therefore show that the widely held view among economists that providing more financial compensation increases the likelihood of participation does not hold in livestock disease control.

The role of trust and social norms

The most important control beliefs in chapter 4 were related to farmers' information needs and the role of perceived trust and confidence in the disease control strategy chosen by animal health authorities. The role of trust and social norms was studied in more detail using discrete choice experiment methodology in chapter 6, and subsequently using an agent-based model in chapter 7. Two other vaccination scheme attributes in the choice experiment were defined for this purpose, one about the way government information was provided to farmers (none, via leaflets, via veterinarians, or both) and the other about the vaccine adverse effects probability (significant, small, negligible), capturing farmers' perceived trust and confidence in the vaccine safety and effectiveness. The results of the econometric model showed that farmer's attitude interacted positively with information provided via veterinarians while descriptive norm interacted positively with a lower perceived adverse effects probability.

The agent-based model simulated the interplay between farmers' collective behaviour and bluetongue disease epidemiology. The utility model specification from chapter 6 described the decision-making process of farmers. Other components added that made the model dynamic were a social network structure to describe the diffusion process of sharing information about vaccination status and a susceptible-latent-infectious-recovered (SLIR) model to describe the disease spread. The effectiveness of different bluetongue vaccinations scheme designs was studied as measured by disease rate and vaccination uptake.

Vaccination schemes that focused more on motivating farmers via informational instruments were more effective than predicted from the comparative static analysis in chapter 6. Motivation via financial incentives resulted in a lower effectiveness than was predicted from that same model. With vaccination scheme designs that aim at serving farmers' information needs, a group of farmers is readily motivated to vaccinate. These farmers in turn positively influence other farmers in their social network to vaccinate. This emergent social interaction effect is strengthened with raising perceived trust and confidence in the disease control approach. Vaccination is more likely to happen if farmers perceive that others in their social network who yet vaccinated experience no adverse effects.

8.3 Implications for policy making

For several reasons, designing policies for the control of livestock diseases in the Netherlands is a complex task. National animal health and livestock disease control in Europe is more and more coordinated supranationally via the European Union and the World Organisation for Animal Health. Policy makers need to have a good working knowledge of national and supranational legislation regarding livestock disease control. At the same time they need to give account to society for their policy choices.

In the forthcoming paragraphs some suggestions are made for improving the design of future livestock disease control policies based on a voluntary approach. The implications for policy making are better understood when first some attention is given to *recent developments in the governance of livestock disease control*. The key behavioural determinants of the willingness to vaccinate found in this thesis are then shortly described, and given the heterogeneity in motives it is discussed next *what policy makers can do to persuade farmers to cooperate*. The final paragraphs have some concluding remarks *on the regulatory context of disease control approaches.*

Recent developments in the governance of livestock disease control

During the past bluetongue epidemic of 2006 to 2009, the Netherlands, England and Wales opted for a voluntary vaccination scheme (Wilson and Mellor, 2009). At the same time, policy makers in these countries have considered using insights from behavioural economics and social psychology in the design of policies (Collier et al., 2010; Stroeker, 2016). That is making use of people's systematic cognitive biases and heuristics and frame choices in a way that leads to the desired behaviour (also called nudging). It is based on the notion that behaviour is governed not only by reflective and conscious processes but also by automatic and unconscious processes (Ölander and Thøgersen, 2014). Following the formation of a Behavioural Insights Team (BIT) in 2010 in the United Kingdom, in the Netherlands a network of BITs are now formed, for example at the Ministry of Economic Affairs (Ministry of Economic Affairs, 2016). Also the Netherlands Food and Consumer Product Safety Authority (NVWA) is involved.

In recent years, the governance of animal health and livestock disease control is shifting in the direction of a neoliberal model of cost and responsibility sharing (Bergevoet et al., 2011). The idea behind this model is that when farmers have more control over their actions and have to pay for the consequences, then they will take more interest in disease prevention and control actions and act more responsibly (Anonymous, 2006). Neoliberalism is a contemporary variant of liberalism. According to Humphreys (2009), neoliberalism is based on three core principles: marketisation, an enhanced role for the private sector, and deregulation and voluntarism. Individual people and firms know what is best for themselves, and should be free to pursue their own interests. Transactions should occur via market mechanisms. Deregulation is important to let markets work more effectively and efficient. The government's main role is to secure property rights and act as an initiator, for example to create a 'tradeable phosphate rights' system. Regulation should be soft and optional (e.g. via subsidization). However, it should be noted that with the openness towards using nudging, policy makers, in fact, use forms of paternalism (Thaler and Sunstein, 2003).

What policy makers can do to persuade farmers to cooperate

First of all, policy makers need to account for heterogeneity among farmers in their motivation to invest in livestock disease control (Barnes et al., 2015; Ochieng' and Hobbs, 2016). Some farmers will see vaccination mainly as a way to insure against the production risk from disease infection. They perceive the risk of disease infection as high and consequences as large. Results in chapter 6 indicated that farmers who operate large and intensive farms or who keep heifers for export were more likely to vaccinate.

Other farmers might be more concerned about the adverse effects of vaccination. They do not want to be confronted with animal suffering but keep job satisfaction high from working with healthy animals. Results in chapter 3, 4 and 6 suggest that farmers can have social and intrinsic motives to participate in disease control programs. For example, they consider what important referents, such as the veterinarian or family members, think they should do and take into account the perceived behaviour of peers.

A 'one size fits all' policy is likely ineffective in livestock disease control given the above. Different policy instruments have to be deployed to reach different groups of farmers who vary in motives to invest in livestock disease control. Three main types of policy instruments are commonly distinguished: financial, incentive based (carrots), regulative (sticks), and informational (promises or sermons) instruments (Rothschild, 1999; Bemelmans-Videc et al., 2011). Some authors see motivational or social interaction mechanisms, such as social pressures from a group as a fourth type of policy instrument to motivate participation (Leeuwis, 2007; Collier et al., 2010).

Given the actual view on how diseases should be managed in the society, it can be argued that information and communication tools are the most obvious policy instruments to inform and/or persuade farmers about the need to participate in government-initiated livestock disease control policies. Farmers should have a deliberate choice to participate in interventions that serves private and public objectives, and should be given the possibility to compare their risk perceptions with factual information about the expected probabilities and monetary and non-monetary consequences of disease infection with and without the disease control intervention.

Farmers in the two samples used in this thesis, on average, expressed a fairly positive evaluation of performing vaccination against bluetongue. This means that for many of them their internal motivation is likely increased by reasoned opinions (Leeuwis, 2007). A well thought-out risk communication strategy considers that information is more likely accepted if the source and message characteristics are perceived as credible and trustworthy. It is therefore advisable to communicate more via personal and local rather than anonymous and distant sources, provided that there is agreement on the approach taken by the government. Results of chapter 4 and 6 suggest that the most obvious communicator would then be the veterinarian.

The role of subsidization in addition to information provision remains somewhat unclear. Economists often advise policy makers to use subsidization to compensate farmers for the positive off-farm effects (externalities) from livestock disease control investments such as herd vaccination. Oher views are that accepting financial compensation is a free choice which can be rejected or that financial compensation manipulates behaviour by making the desired choice more appealing (Rothschild, 1999). Results of this thesis on the role of subsidization in voluntary vaccination against bluetongue are as follows. It was pointed out in chapter 2 and 6 that production risks and the guarantee to continue export of animals might already be sufficient for a group of farmers to recognise the economic benefits, so that financial compensation is not needed to have a net return from vaccination. Furthermore, for the bluetongue vaccination problem a crowding-out effect was found in chapter 6 between injunctive norm and government subsidy. Farmers who felt more social pressures from perceptions of what referents think what ought to be done were less likely to vaccinate with providing more subsidy. This can occur when “when incentives adversely affect individuals’ altruism, ethical norms, intrinsic motives to serve the public, and other social preferences” (Bowles and Polanía-Reyes, 2012, p. 368).

Compensation rules in plant and animal health in the European Union are pre-defined to prevent decisions on compensation to be crisis driven and to sustain cooperation for future risk reduction (Mumford, 2011). In case of vaccination as the control measure, one hundred per cent of the cost of supply of the vaccine and fifty per cent of the costs of administering are normally compensated for (European Council, 2008). The crowding-out effect that was previously described could be minimised by explaining better what the meaning is of providing subsidy and where the financial sources come from. The reasons for developing a community fund, as explained in the Council Decision 90/424/EEC (European Council, 2006), should be known by the farming community. The level of subsidy and the manner in which compensation and reimbursement is offered to farmers can have a signalling function, indicating the extent to which the government takes the issue seriously.

Using motivational, social interaction or nudging mechanisms are seen as a fourth type of policy instrument. One such nudge is already implicitly described, which is the use of communication channels for information sharing that are perceived as credible and trustworthy. Another nudge relates to using descriptive norms (herd behaviour) as social pressures to induce behaviour. In the context of bluetongue vaccination, results of chapter 6 and 7 suggest that perceived social pressures to vaccinate to increase the uptake level become effective only when farmers have trust and confidence in the suggested approach to control the disease. Trust and confidence also relate to perceptions about the safety and effectiveness of the vaccine.

On the regulatory context of disease control approaches

The regulatory context for the control of livestock diseases is closely linked to the economic and societal impact that these diseases can have (Wilkinson et al., 2011). According to a framework developed by the International risk governance council, bluetongue might fall in the so-called 'ambiguous' risk category (Renn, 2005). This means that farmers and other stakeholders have different interests, goals and ideas about the severity of the risks associated with bluetongue (Roodenrijs et al., 2014). The focus in this thesis was on understanding farmers' willingness to vaccinate against (the re-emergence of) bluetongue under different policy designs. Results were based on surveys from dairy farmers with a herd size of at least 40 dairy cows. Other relevant farmer stakeholders such as hobby holders keeping ruminants, commercial livestock farmers in sheep and goat sectors or veterinarians were not sampled.

Only collective vaccination could halt a disease epidemic, requiring a high uptake. In the first sample used in chapter 3, 4 and 5, about 25 per cent of the farmers were so-called ‘non-intenders’, about 35 per cent ‘undecided’ and about 40 per cent ‘intenders’. In the second sample used in chapter 6 and 7, the average vaccination uptake was estimated between 48 and 68 per cent, depending on the perceived adverse effects probability, the way government information was provided to farmers and the level of government subsidy. Whether to opt for a voluntary approach or a command-and-control approach of regulation and enforcement to livestock disease control is dependent on farmers’ willingness to act, which in turn is dependent on the approach chosen (May, 2005a; May, 2005b).

The methodology used in this thesis mainly studied how the design of policies can be improved given the heterogeneity in motives to invest in livestock disease control. As such, only the short-term effects related to the (cost-)effectiveness of different designs were studied. The long-term effects of the control approach selected could be important as well as farmers in the qualitative research stage still referred back to a vaccination campaign in 1999 against infectious bovine rhinotracheitis, in which a batch of vaccines was contaminated (Barkema et al., 2001; Elbers et al., 2010). Throughout this thesis, using different samples and research methods, the importance of trust and confidence was highlighted. Voluntary approaches embedded in social capital, such as norms of reciprocity, reputation, and solidarity, have the potential to overcome collective action problems.

8.4 Main scientific contributions

This thesis started with the application of two normative models of decision making to the case of voluntary vaccination against the bluetongue disease. The expected utility theory from economics was used in chapter 2 and the reasoned action approach from social psychology was used in chapter 3 and 4. Both models of decision making are frequently used in the domain of economics of animal health. Three research themes for livestock disease control were subsequently worked out in the chapters 5 to 7 (see also section 8.2): how farmers cope with risk in the context of livestock diseases, on the usefulness of financial compensation as a policy instrument, and the role of trust and social norms. The main overall scientific contribution of this thesis to the domain of economics of animal health has been to connect several (social) psychological concepts with economic theories, mainly for the purpose to explain variation in farmer decision making and behaviour. More specific contributions are discussed in the forthcoming paragraphs.

First, in this thesis, recent advances in reasoned action theory (Fishbein and Ajzen, 2010) have been applied for the first time in the domain of economics of animal health. Compared to preceding versions, i.e. the theory of reasoned action (Fishbein and Ajzen, 1975) and the theory of planned behaviour (Ajzen, 1991), the reasoned action approach (Fishbein and Ajzen, 2010) pays attention to different dimensions that underlie the key social-psychological constructs that explain intention. For example, based on advancements in research about different types of norms, in chapter 3 injunctive norms were distinguished from descriptive norms instead of only measuring social norms. These theory advancements have come along with advancements in multivariate statistical techniques. A special case of structural equation modelling, called multiple indicators and multiple causes model (Jöreskog and Goldberger, 1975; Diamantopoulos and Winklhofer, 2001; Diamantopoulos, 2006), was applied in chapter 4, and therewith introduced for the first time in the domain of economics of animal health to assess the most influential beliefs that indirectly explain intention. The potential mediating role of background variables, such as perceived risk and personality traits, is explicitly accounted for in the reasoned action approach framework. An application of using these background variables to explain heterogeneity in farmers' beliefs was the subject of research in chapter 5.

Second, this thesis contains the second discrete choice experiment in the domain of economics of animal health that specifically evaluated farmers' preferences for vaccination scheme design attributes, after the study of Bennett and Balcombe (2012). The application of an integrated choice and latent variable model approach from marketing and transport economics in chapter 6 is novel to the agricultural and animal health economics literature. This model is based on generalised random utility theory (Walker, 2001; Walker and Ben-Akiva, 2002; Ben-Akiva et al., 2012) and offers a general econometric framework to supplement economic theory with concepts or theories from social sciences. The idea of integrating social-psychological constructs into choice models to explain preference heterogeneity is not new (e.g. Onozaka et al., 2011; Grebitus et al., 2013; Greiner, 2015), but the integrated choice and latent variable model framework in these aforementioned studies was not considered. The more formal integration of a latent variable model with a choice model gives an improvement over conventional choice models that simply integrate social-psychological constructs as covariates, in terms of reducing measurement error and potential endogeneity bias (e.g. Ashok et al., 2002; Vij and Walker, 2016).

Third, this thesis contributed to the economic literature on the modelling of the interplay between farmers' collective behaviour and disease epidemiology by presenting a bottom-up approach by means of an agent-based model in chapter 7. The utility model developed in chapter 6 was connected with a social network structure and an epidemiological model. Existing studies based on mainly information economics approaches, principal-agent theory and game theory emphasize the importance of proper financial incentives to invest in voluntary livestock disease control (e.g. Hennessy et al., 2005; Gramig et al., 2009; Horan et al., 2015; Wang and Hennessy, 2015). The results of chapter 7 highlight the importance of serving farmers' information needs and of raising perceived trust and confidence in the disease control approach chosen by animal health authorities.

8.5 Future research

The study of the appropriateness of voluntary approaches in policy making is not bounded to livestock disease control but is found in many policy areas and mostly link to conservation and other environmental issues. A search on Scopus with the query 'TITLE-ABS-KEY (voluntary AND (agricultur* OR farm*)) AND (polic*)', resulted in 708 scientific publications. Figure 1 shows the number of publications over time and reveals that it is an growing study topic of interest.

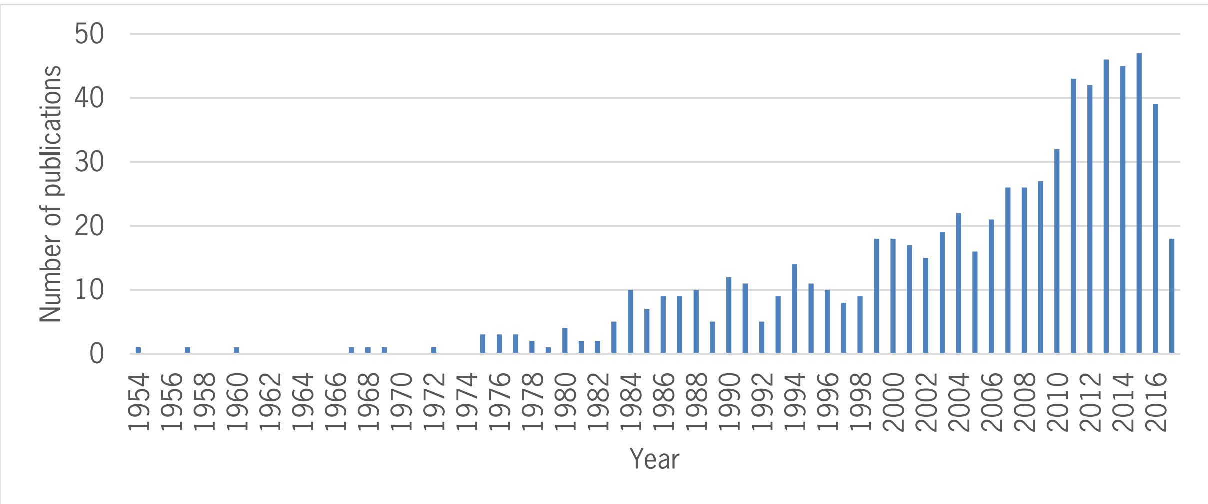


Figure 8-1: Number of publications by year from Scopus indicating the increase in research into voluntary approaches in policy making.

There is ample empirical scientific evidence that farmers' behaviour that involves private and public objectives, does not always follow the standard economic model, based on economic rationality. The type of research done in this thesis can be extended to many other decision problems that have societal relevance, and that involve potential conflicts between private and collective interests. Policy design could improve from understanding first how farmers likely act to a government intervention. This information is of particular interest for policy makers who have to justify for their budget spending while their policies should be cost-effective in reaching the formulated goals. The specific contribution of economic theory with its notions of e.g. resource allocation, economic efficiency, and opportunity costs, over other social science disciplines such as sociology or psychology to policy making is its ability to quantify different policy outcomes and the consideration of uncertainty (Pannell, 2004).

The main research themes that were identified and discussed in section 8.2 and 8.4 – how farmers cope with risk, the usefulness of financial compensation as a policy instrument, and the role of trust and social norms could be elaborated further in the light of recent findings and insights from the field of human judgement and decision making. A key concept that extends to all disciplines in this field is the distinction between intrinsic and extrinsic motivation. Motivations in economic theory are just manifestations of underlying preferences; The extrinsic type of motivation is considered only in decision models that assume economic rationality via (mainly monetary) incentives coming from outside the decision maker. Future research could try to empirically test new theoretical economic viewpoints such as the idea of motivational crowding (Frey and Jegen, 2001; Gneezy et al., 2011; Bowles and Polanía-Reyes, 2012).

One line of future research will be proceeding with the application of reasoned action theory (Fishbein and Ajzen, 2010). The latter does not impose restrictions on the type of motivation. It is a flexible theory in the sense that constructs or background variables (see chapter 5) which are hypothesized to be relevant for a decision problem are easily added to the key social-psychological constructs of attitude and social norms to explain behaviour (see e.g. Onwezen et al., 2013; Onwezen et al., 2014; van Dijk et al., 2015; van Dijk et al., 2016). In an excellent book chapter in which Icek Ajzen discusses the position of social psychology in the field of human judgment and decision making (1996), he shows that expected utility theory and reasoned action theory have similar ideas how people come to their decisions as both rely on the expectancy-value model (Feather, 1959; Feather, 1982). He argues that rational choice models are not the most accurate description of the way decisions are made, but rather an ideal or normative model based on statistical principles of probability and logic. Reasoned action theory deals with decision making in the more general context of predicting and explaining behaviour but is less sophisticated from an econometric perspective, as often simple rating (Likert) scales are used from which e.g. no welfare implications can be derived. This type of research could also be interesting for private actors in the agricultural sector, such as accountancy firms, banks or buyers, who have an economic relationship with farmers and want to improve consultancy or optimise collaboration in the supply chain.

A second line of future research will be to discover the usability of experimental methods in economics to understand and predict farmers' behaviour. One such method, the discrete choice experiment which belongs to the family of stated preference methods, was applied in this thesis, in chapter 6. It makes use of surveys that are sent to a sample of farmers by mail, via the internet, or both. Discrete choice experiment methodology continues to improve on different aspects. The application in this thesis focused on explaining preference heterogeneity from a behavioural point of view using the integrated choice and latent variable model framework (e.g. Ben-Akiva et al., 2012).

Other experimental methods are framed field experiments (Harrison and List, 2004) or extra-laboratory experiments (Charness et al., 2013). One promising application of such experiments are so-called business simulation games (Holst et al., 2014; Buchholz et al., 2016; Moser and Mußhoff, 2016; Freudenreich and Mußhoff, 2017; Hermann et al., 2017). Within a decision-making environment that is made as realistically as possible, farmers in aforementioned studies were asked to make a series of production decisions under different policy designs (the treatment effect). Such research methods could be very well used to study farmer behaviour for all research themes that were identified and discussed in section 8.2 and 8.4 of this chapter.

8.6 Main conclusions of this thesis

- Dutch dairy farmers who operate large-scale and intensive farms or keep heifers for export are likely to have private economic motives to vaccinate against bluetongue (Chapter 2, 4, 5 and 6).
- Farmers' willingness to vaccinate against bluetongue is mostly driven by attitude, followed by perceived social pressures from injunctive and descriptive norms. This implies farmers can be motivated intrinsically, extrinsically, or both (Chapter 3).
- Dutch dairy farmers have intrinsic motives to vaccinate against bluetongue. They do not want to be confronted with animal suffering but want to keep job satisfaction high from working with healthy animals (Chapter 4).
- Dutch dairy farmers have social motives to vaccinate against bluetongue. They consider what important referents, such as the veterinarian or family members, think they should do and take into account the perceived behaviour of peers (Chapter 3 and 4).
- Perceived risk, personality traits and past behaviour are important behavioural variables for explaining the heterogeneity in beliefs to vaccinate against bluetongue (Chapter 5).
- The efficacy of financial, incentive based instruments to motivate to vaccinate against bluetongue is heterogeneous and not necessarily positive for each farmer. They are not effective if farmers already expect a positive net benefit from vaccination or if they crowd-out the motivation to comply with the vaccination policy (Chapter 2, 4, 6, 7).
- The efficacy of informational policy instruments to motivate farmers to vaccinate against bluetongue is positively affected by farmers' attitude towards vaccination and in case farmers perceive the communication channels used as credible and trustworthy (Chapter 3, 4, 6).
- The efficacy of social interaction mechanisms in policy making, such as the perceived social pressure to vaccinate against bluetongue, is positively affected by farmers' trust and confidence in the government approach to control the disease (Chapter 4, 6, 7).

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Addendum

Summary

Animal health authorities in the European Union nowadays consider voluntary approaches based on a neoliberal model of cost and responsibility sharing as a tool for controlling livestock diseases. Policy makers aim for policies that are soft and optional, and use insights from behavioural economics and social psychology. Voluntary approaches are flexible in terms of legislation and can be effective at lower costs, provided that farmers are willing to participate. In 2008, the Dutch animal health authorities used a voluntary vaccination approach to control an emerging bluetongue epidemic that started end of 2006. Nearly 60,000 holdings with ruminants were already affected by the end of 2007 and experts indicated that transmission could only be stopped through mass vaccination. Farmers were motivated to participate by informational and financial, incentive-based policy instruments.

Economic theory predicts that farmers underinvest in private disease control measures in the presence of externalities. These studies, however, assume farmers only consider the private economic motives and that they only can be extrinsically motivated via (monetary) incentives. If the willingness to invest in livestock disease control is also driven by intrinsic and social motives, this could imply that not only financial compensation, but a mix of policy instruments is needed to make voluntary approaches work.

The overarching research objective of this thesis was to assess the key determinants of farmers' willingness to vaccinate against bluetongue and study the impact of different policy designs on the effectiveness of voluntary vaccination approaches to bluetongue disease control.

A three-stage research approach was conducted. Two models of decision making, one from economics and one from social psychology, were first applied to the case study to obtain a solid understanding of important perceptions and motivations that farmers have to invest in livestock disease control. These motivations (sometimes incentives) and perceptions were then related to different attributes of a vaccination scheme to have a better understanding of how a higher uptake can be obtained. In the third stage, the effect of the interplay between farmers' collective behaviour and disease epidemiology on disease rate and vaccination uptake was studied.

Expected utility theory was used in combination with decision analysis and Monte Carlo simulation in chapter 2. The economic risk and monetary outcomes of the vaccination decision were considered, intrinsic or social motives ignored. The theoretical expectation from the analysis is that with high probabilities of herd exposure and disease effects at the start of the outbreak the farmer decides to vaccinate. Re-vaccination is uncertain during the course of the epidemic due to a lower

probability of herd exposure and enduring protection against infection from previous vaccination. Factors that make re-vaccination more likely to happen are risk-averse behaviour and farm management aimed at the export of heifers. The decision moment – before or during an epidemic – and the characteristics of the disease – endemic, epidemic or emerging – are important factors in perceptions of disease risk.

Chapters 3 to 5 used data from a survey that was based on the reasoned action approach. Data were analysed with a variety of statistical, mostly multivariate, techniques. The relative importance of the social-psychological constructs in predicting the intention to participate in a hypothetical reactive vaccination scheme against bluetongue was assessed in chapter 3. It was found that intended vaccination behaviour was mainly explained by farmers' attitude, but also by social pressures from injunctive and descriptive norms. Perceived behavioural control was the least important predictor of intention.

The most influential beliefs underlying the social-psychological constructs were assessed in chapter 4. Results suggested that instrumental beliefs (e.g. risk reduction) as well as experiential beliefs (e.g. animal welfare) were important drivers of the attitude towards vaccination against bluetongue. This indicates that in addition to monetary outcomes of the decision, at least a group of farmers also consider the non-monetary (or non-pecuniary) outcomes. The results further showed that the most influencing referents for the farmer are the veterinarian, his or her family members and colleague dairy farmers (peers). Two influencing control beliefs were associated with the provision of information and perceived trust and confidence in the vaccine safety, effectiveness and government approach to control the disease.

The aim of chapter 5 was to explore factors that could explain heterogeneity in farmers' attitudinal beliefs. In particular, perceived risk, measured by a relative risk attitude and risk perception, and the Big Five personality traits were associated with variability in these beliefs. Conscientiousness discriminated farmers into a group of 'vaccination intenders' and non-intenders although it remained somewhat unclear how it relates to the decision problem, as it can be a sense of duty, achievement striving or both. The perceived risk measures were related to the milk production intensity and also discriminated intenders from non-intenders. These differences in perceived risk indicated that farmers might not be commonly risk averse, however, it is important to account for the domain specificity of risk taking behaviour.

A survey-based discrete choice experiment was used in chapter 6 to study more deeply farmers' choices for different voluntary bluetongue vaccination scheme designs. A generalised random utility model of farmers' behaviour allowed for heterogeneity in motives to invest in bluetongue disease control. Results showed that farmers have private economic motives (incentives) to participate in a vaccination scheme, such as to insure the production risk from disease infection and to maintain the export of heifers.

Interaction effects found between social-psychological constructs and specific designs of policy instruments highlighted the importance of perceived trust and confidence in the vaccine safety and effectiveness and in the disease control strategy chosen by animal health authorities. Attitude interacted positively with government communication (information) provided via veterinarians. Descriptive norm interacted positively with a lower perceived probability of adverse effects. This suggests that farmers are more likely to vaccinate if they perceive that others in their social network perform vaccination without experiencing adverse effects. Injunctive norm interacted negatively with a higher level of government subsidy. This suggested a crowding-out mechanism through which subsidization adversely affect farmer's motivation to comply with the vaccination policy.

The interplay between farmers' collective behaviour and bluetongue disease epidemiology was studied in chapter 7 with an agent-based model. The utility model specification from chapter 6 was used to describe the decision-making process of farmers. Other components that added to the dynamic nature of the model were a social network structure of the diffusion process of sharing information about vaccination status and a susceptible-latent-infectious-recovered model of disease spread. The effectiveness of different bluetongue vaccinations scheme designs was studied as measured by disease rate and vaccination uptake.

Results of chapter 7 showed that vaccination schemes that focus more on motivating farmers via informational instruments were somewhat more effective than predicted from the comparative static analysis in chapter 6. Motivation via financial incentives resulted in a somewhat lower effectiveness than was predicted from that same model. This might be explained as an emergent effect that evolves under specific vaccination scheme designs from the interactions between farmers themselves and with the environment from which they observe the progress of the disease. These schemes focus more on serving the information needs of farmers and raising the perceived trust and confidence in the disease control approach rather than on incentivising with higher levels of subsidy.

Three themes for livestock disease control emerged from the synthesis of the results in chapter 8, which were subsequently discussed in relation to the wider economic and (social) psychological literature. These themes coincide with shortcoming of the standard economic model of rational choice to describe and predict behaviour. The first theme was about *understanding how farmers cope with risk* in the context of livestock diseases. The second theme focused on *the usefulness of financial compensation as a policy instrument*. The third theme discussed *the role of trust and social norms*. After discussing the implications for policy making, main scientific contributions and suggestions for future research, the chapter concluded that:

- Dutch dairy farmers who operate large-scale and intensive farms or keep heifers for export are likely to have private economic motives to vaccinate against bluetongue (Chapter 2, 4, 5 and 6).
- Farmers' willingness to vaccinate against bluetongue is mostly driven by attitude, followed by perceived social pressures from injunctive norms and descriptive norms. This implies farmers can be motivated intrinsically, extrinsically, or both (Chapter 3).
- Dutch dairy farmers have intrinsic motives to vaccinate against bluetongue. They do not want to be confronted with animal suffering but want to keep job satisfaction high from working with healthy animals (Chapter 4).
- Dutch dairy farmers have social motives to vaccinate against bluetongue. They consider what important referents, such as the veterinarian or family members, think they should do and take into account the perceived behaviour of peers (Chapter 3 and 4).
- Perceived risk, personality traits and past behaviour are important behavioural variables for explaining the heterogeneity in beliefs to vaccinate against bluetongue (Chapter 5).
- The efficacy of financial, incentive based instruments to motivate to vaccinate against bluetongue is heterogeneous and not necessarily positive for each farmer. They are not effective if farmers already expect a positive net benefit from vaccination or if they crowd-out the motivation to comply with the vaccination policy (Chapter 2, 4, 6, 7).
- The efficacy of informational policy instruments to motivate farmers to vaccinate against bluetongue is positively affected by farmers' attitude towards vaccination and in case farmers perceive the communication channels used as credible and trustworthy (Chapter 3, 4, 6).
- The efficacy of social interaction mechanisms in policy making, such as the perceived social pressure to vaccinate against bluetongue, is positively affected by farmers' trust and confidence in the government approach to control the disease (Chapter 4, 6, 7).

Samenvatting

Diergezondheidsautoriteiten in de Europese Unie overwegen steeds meer een vrijwillige aanpak, gebaseerd op een neoliberaal model van het delen van kosten en verantwoordelijkheden, als instrument voor beheersing van dierziekten. Beleidsmakers streven naar beleid dat 'soft' en optioneel is, en gebruiken inzichten vanuit gedragseconomie en sociale psychologie. Een vrijwillige aanpak is flexibel qua wetgeving en kan kunnen effectief zijn tegen lagere kosten, op voorwaarde dat boeren bereid zijn om deel te nemen. In 2008 stelden de Nederlandse diergezondheidsautoriteiten een vrijwillig vaccinatieprogramma in om een emergente blauwtongepidemie te kunnen beheersen, die eind 2006 opgekomen was. Bijna 60.000 bedrijven met herkauwers waren al geïnfecteerd geraakt tegen het einde van 2007 en experts gaven aan dat de transmissie alleen beheerst kon worden door middel van massavaccinatie. Boeren werden gemotiveerd om deel te nemen met beleidsinstrumenten gericht op het verstrekken van informatie en financiële compensatie.

Economische theorie voorspelt dat boeren onderinvesteren in maatregelen gericht op beheersing van dierziekten in de aanwezigheid van externaliteiten. Deze studies veronderstellen echter dat boeren alleen economische drijfveren hebben en dat ze alleen extrinsiek gemotiveerd kunnen worden door middel van monetaire prikkels. Indien de bereidheid om te investeren in dierziektebeheersing ook gedreven wordt door intrinsieke en sociale drijfveren, zou dat kunnen betekenen dat niet alleen financiële compensatie, maar een mix van beleidsinstrumenten nodig is om een vrijwillige aanpak te bewerkstelligen werkzaam te maken.

Het overkoepelende onderzoeksdoel van dit proefschrift was het vaststellen van de belangrijkste determinanten van de bereidheid van boeren om te vaccineren tegen blauwtong en het bestuderen van de impact van verschillende beleidsontwerpen op de effectiviteit van vrijwillige vaccinatieprogramma's gericht op de beheersing van blauwtong.

De onderzoeksaanpak werd uitgevoerd in drie fasen. Allereerst werden twee modellen van besluitvorming, één uit de economie en één uit de sociale psychologie, toegepast op de casus voor het verkrijgen van een goed begrip van de belangrijkste percepties en motivaties die boeren hebben om te investeren in de dierziektebeheersing. Deze motivaties (soms prikkels) en percepties werden vervolgens gerelateerd aan verschillende attributen van een vaccinatieprogramma om beter te begrijpen hoe een hogere opname kan worden verkregen. In de derde fase werd het effect van het samenspel tussen het (collectieve) gedrag van boeren en epidemiologie van ziekte op de mate van ziektegevallen en vaccinatiegraad bestudeerd.

De theorie van verwacht nut werd gebruikt in hoofdstuk 2 in combinatie met beslisanalyse en Monte-Carlosimulatie. Economisch risico en monetaire uitkomsten van vaccinatiebeslissingen werden overwogen, intrinsieke of sociale drijfveren buiten beschouwing gelaten. De theoretische verwachting uit de analyse is dat de boer in geval van hoge kansen op blootstelling van de kudde aan infectie en ziekte-effecten aan het begin van de uitbraak besluit te vaccineren. Opnieuw vaccineren is onzeker tijdens het verloop van de epidemie als gevolg van een lagere kans op blootstelling en blijvende bescherming tegen infectie van eerdere vaccinatie. Factoren die opnieuw vaccineren meer waarschijnlijk maken zijn risico-avers gedrag en bedrijfsbeheer gericht op export van vaarzen. Het moment van besluiten – vóór of tijdens een epidemie – en de karakteristieken van de ziekte – endemisch, epidemisch of emergent – zijn belangrijke factoren in de perceptie van ziekterisico.

De hoofdstukken 3 tot en met 5 waren zijn gebaseerd op data van een enquête die werd ontworpen op basis van het beredeneerd gedragsmodel. Gegevens werden geanalyseerd met een verscheidenheid aan statistische, meestal multivariate, technieken. Het relatieve gewicht van de sociaal-psychologische constructen in het voorspellen van de intentie om deel te nemen aan een hypothetisch reactief vaccinatieprogramma tegen blauwtong werd vastgesteld in hoofdstuk 3. Gevonden werd dat voorgenomen vaccinatiegedrag voornamelijk verklaard woerdt door de attitude ten opzichte van vaccinatie van boeren, maar ook door sociale druk van injunctieve en descriptieve normen. Ervaren controle over het gedrag was de onbelangrijkste minst belangrijkste predictor van intentie.

De invloedrijkste meest invloedrijke overtuigingen onderliggend aan de sociaal-psychologische constructen werden vastgesteld in hoofdstuk 4. De uitkomsten suggereerden dat instrumentele overtuigingen (bijv. over risicoreductie) en ervaringsgerichte overtuigingen (bijv. over dierenwelzijn) de attitude ten opzichte van vaccinatie tegen blauwtong stururden. Dit geeft aan dat in aanvulling op de monetaire uitkomsten van beslissingen een deel van de boeren ook niet-monetaire uitkomsten overweegt. , tenminste een groep van boeren ook de niet-monetaire uitkomsten overweegt. De uitkomsten lieten verder zien dat de meest invloedrijke referenten voor de boer de dierenarts, familieleden en collega-boeren zijn. Twee overtuigingen met betrekking tot ervaren controle waren geassocieerd met het verstrekken van informatie en het ervaren vertrouwen in de veiligheid van het vaccin, de effectiviteit en de overheidsaanpak van de beheersing van de ziekte.

Het doel van hoofdstuk 5 was het verkennen van factoren die de heterogeniteit in gedragsovertuigingen konden verklaren. Met name konden waargenomen risico, gemeten als een relatieve risicoattitude en ervaren risico, en de 'Big Five'- persoonskenmerken worden geassocieerd met variabiliteit in de overtuigingen. Zorgvuldigheid onderscheidde boeren van elkaar in een groep van 'voorgenomen vaccineerders' en 'niet-voorgenomen vaccineerders', alhoewel het onduidelijk bleef hoe dit relateert aan het beslisprobleem, omdat het kan slaan op plichtsgevoel, prestatiestreven, of beide. De meetinstrumenten voor waargenomen risico meetinstrumenten waren gerelateerd aan de intensiteit van melkproductie en onderscheidden 'voorgenomen vaccineerders' van niet-voorgenomen' vaccineerders. Deze verschillen in waargenomen risico suggereren dat boeren niet in het algemeen risicoavers zijn, het is echter van belang om hierbij rekening te houden met de domeinspecificiteit van risicogedrag.

Een enquête-gebaseerd discreet keuze-experiment werd toegepast in hoofdstuk 6 voor het dieper bestuderen van de keuzes van boeren uit verschillende vrijwillige vaccinatieprogramma-ontwerpen voor de beheersing van blauwtong. Een gegeneraliseerd willekeurig nutsmodel van het gedrag van boeren stond toe voor heterogeniteit in drijfveren om te investeren in dierziektebeheersing voor blauwtong. De uitkomsten lieten zien dat boeren economische drijfveren (prikkels) hebben om deel te nemen aan een vaccinatieprogramma, zoals het verzekeren van de productierisico's afkomstig van dierziekte-infectie en het behouden van de mogelijkheid van export van vaarzen.

Interactie-effecten tussen sociaal-psychologische constructen en specifieke ontwerpen van beleidsinstrumenten benadrukten het belang van ervaren vertrouwen in de veiligheid van het vaccin, de effectiviteit en de overheidsaanpak van de beheersing van de ziekte. Attitude interacteerde positief met informatie van de overheid verspreid via dierenartsen. Descriptieve norm interacteerde positief met een lager ervaren kans op bijwerkingen van het vaccin. Dit suggereert dat boeren meer geneigd zijn om te vaccineren wanneer zij merken dat anderen in hun sociale netwerk vaccineren zonder bijwerkingen te ervaren. Injunctieve norm interacteerde negatief met een hoger niveau van overheidssteun. Dit suggereert een verdringingmechanisme waardoor subsidiëring de motivatie van boeren om aan het vaccinatiebeleid te voldoen nadelig beïnvloedt.

Het samenspel tussen het (collectieve) gedrag van boeren en epidemiologie van ziekte werd bestudeerd in hoofdstuk 7 met een 'agent-based' (computationeel) model. De nutsmodelspecificatie uit hoofdstuk 6 werd gebruikt om het besluitvormingsproces van boeren te beschrijven. Andere componenten die werden toegevoegd voor het dynamische karakter van het model waren een sociale netwerkstructuur van het verspreidingsproces van het delen van informatie over de vaccinatiestatus en een 'vatbaar-latent-infectieus-hersteld'-model van de ziekteverspreiding. De effectiviteit van verschillende vrijwillige vaccinatieprogramma-ontwerpen voor de beheersing van blauwtong werd bestudeerd aan de hand van de mate van ziektegevallen en vaccinatiegraad.

Uit de resultaten van hoofdstuk 7 blijkt dat vaccinatieprogramma's die meer gericht zijn op het motiveren van boeren via informatie–instrumenten enigszins meer effectief waren dan voorspeld op basis van de comparatief-statische analyse uit hoofdstuk 6. Het motiveren via financiële prikkels resulteerde in een enigszins lagere effectiviteit dan was voorspeld door datzelfde model. Dit kan worden uitgelegd als een emergent effect dat ontstaat onder specifieke vaccinatieprogramma-ontwerpen, door de interacties tussen boeren onderling en met de omgeving van waaruit ze de voortgang van de ziekte waarnemen. Deze programma's richten zich meer op het bedienen van de informatiebehoeften van boeren en het versterken van ervaren vertrouwen in de beheersingsaanpak in plaats van het stimuleren met hogere subsidieniveaus.

Drie thema's voor dierziektebeheersing kwamen voort uit de synthese van de resultaten in hoofdstuk 8, welke vervolgens besproken werden in relatie tot de bredere economische en sociaal-psychologische literatuur. Deze thema's vallen samen met tekortkomingen van het standaard-economische model van rationele keuzes voor het beschrijven en voorspellen van gedrag. Het eerste thema ging over een beter begrip van hoe boeren omgaan met risico in de context van dierziekten. Het tweede thema richtte zich op de bruikbaarheid van financiële compensatie als beleidsinstrument. Het derde thema had betrekking op de rol van vertrouwen en sociale normen.

Na het bespreken van de implicaties voor beleid, de belangrijkste wetenschappelijke bijdragen en suggesties voor toekomstig onderzoek, werd in dit hoofdstuk geconcludeerd dat:

- Nederlandse melkveehouders die grootschalig en intensief boeren of vaarzen houden voor de export naar alle waarschijnlijkheid economische drijfveren hebben om te vaccineren tegen blauwtong (hoofdstukken 2, 4, 5 en 6).
- De bereidheid van boeren om te vaccineren tegen blauwtong met name gedreven wordt door de attitude, gevolgd door ervaren sociale druk van injunctieve en descriptieve normen. Dit houdt in dat boeren intrinsiek, extrinsiek of op beide manieren kunnen worden gemotiveerd (hoofdstuk 3).
- Nederlandse melkveehouders hebben intrinsieke drijfveren om te vaccineren tegen blauwtong. Ze willen niet worden geconfronteerd met dierlijk lijden, maar arbeidsvreugde halen uit het werken met gezonde dieren (hoofdstuk 4).
- Nederlandse melkveehouders hebben sociale drijfveren om te vaccineren tegen blauwtong. Ze overwegen wat belangrijke referenten zoals de dierenarts en familieleden, vinden wat zij moeten doen en houden rekening met het verwachte gedrag van collega-boeren (hoofdstuk 3 en 4).
- Waargenomen risico, persoonskenmerken en gedrag in het verleden zijn belangrijke gedragsvariabelen voor het verklaren van heterogeniteit in gedragsovertuigingen om te vaccineren tegen blauwtong (hoofdstuk 5).
- De doelmatigheid van financiële instrumenten voor het motiveren van boeren om te vaccineren tegen blauwtong is heterogeen en niet noodzakelijk positief voor elke boer. Ze zijn niet effectief als boeren al positieve nettobaten verwachten van vaccinatie of wanneer ze de bereidheid om te voldoen aan het vaccinatiebeleid verdringen.
- De doelmatigheid van informatie-instrumenten voor het motiveren van boeren om te vaccineren tegen blauwtong wordt positief beïnvloed door de attitude van boeren ten opzichte van vaccineren en wanneer zij de communicatiekanalen als geloofwaardig en betrouwbaar ervaren.
- De doelmatigheid van sociale interactiemechanismen in beleid, zoals de ervaren sociale druk om te vaccineren tegen blauwtong, wordt positief beïnvloed door het vertrouwen van boeren in de overheidsaanpak van de beheersing van de ziekte.

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Curriculum Vitae

Jaap Sok was born on April 18, 1989, in Ede, the Netherlands. He obtained his bachelor's degree in 2010 and his master's degrees in 2012, both in agricultural economics at Wageningen University. During his studies he worked one day a week for NSure, a company that started in 2006 in Wageningen, developing molecular tests for the agricultural sector. Inspired by this work, he wrote his bachelor's thesis on asymmetric price transmission between producer prices and retail prices in the Dutch fruit sector. During his master program, he became interested in the economics of renewable energy, and wrote two master's theses on this subject.

In August 2012 he started as a PhD student at the Business economics group, which has built a strong reputation over the last decades in animal health economics The PhD thesis assessed the key determinants of farmers' willingness to vaccinate against bluetongue and studied the impact of different policy designs on the effectiveness of voluntary vaccination approaches to bluetongue disease control. In February 2014, he became a lecturer (part-time) and has taught courses in business economics and management accounting since. By the end of 2017 he obtained his PhD degree.

As of January 2018, he will start as an assistant professor at the Business economics group. In his research he aims at using recent findings and insights from the field of human judgement and decision making to study farmers' economic behaviour in decision domains that potentially have conflicts between private and public interests.

Education certificate

Jaap Sok
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Completed Training and Supervision Plan

Wageningen School of Social Sciences

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Writing PhD Research proposal	Wageningen University	2012	6.0
Applied Economic Modelling for the Veterinary Sciences	Utrecht University	2013	3.0
Behavioural and Experimental Economics, ECH-51306	Wageningen University	2013	6.0
Econometric and Mathematical Programming Models for Policy Analysis using FADN Data	WASS	2013	1.5
Agent-Based Modelling of Complex Adaptive Systems, INF-50806	Wageningen University	2014	6.0
Regular PhD meetings	Wageningen University, BEC	2012-2016	4.0
'Farmers' willingness to prevent and control animal diseases'	Animal Health Economics Workshop	2012	1.0
'Expected utility of voluntary vaccination in the middle of an emergent bluetongue virus serotype 8 epidemic'	EAAE PhD workshop, Leuven	2013	1.0
'Using farmers' attitudes and social pressures to design voluntary bluetongue vaccination strategies'	EAAE PhD workshop, Rome	2015	1.0
B) General research related competences			
Introduction course	WASS	2012	1.0
Information Literacy including Endnote Introduction	WGS	2013	0.6
C) Career related competences/personal development			
Competence Assessment	WGS	2013	0.3
Teaching	Wageningen University, BEC		
- Assistant in QVE-20306		2012	0.4
- Assistant in BEC-21806		2013	0.4
- Assistant in BEC-30306		2013	0.8
- Assistant in BEC-51806		2013	1.6
- Assistant in BEC-30306		2014	0.8
Course Lecturing (College geven)	Wageningen University, ESD	2015	1.0
Total			**36.4**

*One credit according to ECTS is on average equivalent to 28 hours of study load.

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